Techniques in

BRITISH SURGERY

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ILLUSTRATED

W B SAUNDERS COMPANY

Philadelphia London 1950

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Preface

THIS BOOK, comprising as it does a number of specially selected articles on surgical subjects and written by twenty-nine leading surgeons, is, I venture to hope, a liberal cross-section of British surgery as practised today.

It may be argued that the section should have been made more obliquely so as to include many more outstanding contributors and to ensure that the widest possible field had been covered. If this book fulfils the high hopes of popularity I confidently anticipate, then no doubt at some future date serial sections will be undertaken.

The contributors, all of whom are in active surgical practice and accomplished teachers, have been asked to draw mainly from their own experience and to present their subjects in their own manner with special emphasis on technique. The articles are, in my opinion, representative of the best this country can show.

I owe a great debt of gratitude to the authors for their enthusiasm, co-operation, and loyalty. This book is truly theirs and is the product of their skill, artistry, and untiring effort. It is typically British.

My thanks are also cordially extended to the numerous medical photographers and artists who have so efficiently illuminated this work with drawings made in the operating room, sketches to clarify special points in technique, skiagrams, and the like.

I am under a great obligation to such eminent authorities as Mr. Tom Jones and Mr. W. C. Shepard for many helpful suggestions in connection with the illustrations. I am particularly indebted to W. B. Saunders Company for publishing this important contribution to British surgery and for their toleration, kindness, encouragement, and constructive criticisms.

To my senior secretary, Miss A. M. Cosham, my grateful thanks are due for her help at all stages of the work.

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PART I

Head, Neck, and Spinal Column

CHAPTER 1

The Management of Head Injuries in Civil Life

G F ROWBOTHAM

THIS CHAPTER deals with injuries to the head resulting from accidents in civilian life and not with the type of injury due to small missiles of high velocity such as occurs in warfare It is addressed to the general surgeon interested in traumatic cerebral surgery and not to the practised neurological surgeon.

Because of the nature of the accident injuries to other parts of the body are common in head injuries Thus, before the nature and severity of a head injury are assessed injuries elsewhere must be sought and their effect on the total clinical picture evaluated

There are two types of injury with which we are concerned

1 *The Compound Wound of the Vault*
   (a) Associated with little disturbance of brain function
   (b) Associated with deep unconsciousness
2 *Closed Head Injuries*
   (c) Without internal compounding
   (d) With internal compounding when a fracture may enter an air sinus and lacerate the overlying dura mater

Management resolves itself essentially into the problem of the treatment of the physical injury of the brain and of the prevention or combating of infection.

THE SURGICAL PROBLEM OF THE BRAIN INJURY

At the moment when the violence is being inflicted the brain can be damaged in three ways It may be (a) contused or (b) lacerated or (c) may suffer a widely scattered neuronal injury One or any combination of these conditions may result

from an injury Secondary pathological phenomena may supervene on this b
injury influencing the clinical picture and possibly altering the prognosis profoun

The Intrinsic Injury

(a) Contusion
(b) Laceration
(c) Diffuse neuronal injury

Secondary Pathological Manifestations

(a) Shock
(b) Intracranial haemorrhage—extradural
—subdural
—subarachnoid
—intracerebral
—intraventricular
(c) Oedema—generalised
—local
(d) Hydrocephalus—internal
—external
(e) Herniations of the brain
(f) Intracranial infections
(g) Epilepsy resulting from the trauma
(h) Loss of blood from superficial wounds
(i) Fat emboli
(j) General effects of injuries to other organs

Patients may be grouped according to the nature and severity of their injuries

Group 1

In about 3 per cent of cases of head injury the intrinsic injury has been minimal but is complicated by the later development of a large surface haemorrhage that compresses the brain Clinically a man recei es a blow on the head is dazed or unconscious for a few moments he reco ers, carries on with his work and then develops headaches becomes confused and finally unconscious This is the type of case in which the latent inter al is characteristic

Group 2

In about 10 per cent of ases the intrinsic injury is overwhelming and irreversible from the onset The patient is deeply unconscious from the time of injury and in a few hours is moribund Temperature and pulse rate rise and respiration, at first rapid becomes irregular It is soon obvious that death is imminent and in fact, it often occurs within thirty six hours of the infliction of the injury

Group 3

In this group the intrinsic injury is of arying severity but is not irre ersible Secondary pathological lesions de elop to influence the pi ture and possibly to produce fatal results if nothing is done to relieve their action In this group the possible pathological complexes are exceedingly numerous and so therefore are the possible clinical pictures

MANAGEMENT OF THE INTRINSIC INJURY

For the lesions of contusion, laceration and diffuse neuronal injury no direct surgical intervention is possible; all that the surgeon can do is to produce the *conditions that he considers most conducive to natural recovery*.

It is important for the surgeon to teach his staff the details of nursing the head-injured, and time spent in this training is well worth while. Regular half-hourly recordings of pulse rate, respiration rate and rhythm, and temperature should be carried out during the first twenty-four hours. In special cases blood-pressure readings and changes in the depth of unconsciousness should also be noted. When a patient shows *definite signs of improvement* these recordings may be made less frequently.

Restlessness

When this stage is reached, even though a patient may be apparently still uncooperative, reassuring and soothing words often do much good in quieting him, since the mind is by this time becoming receptive. It is always wrong to try to restrain a patient's restless movements by force, since he will only resist until he is exhausted. Other methods, such as raising and padding the bed sides, will allow him a certain amount of movement without the danger of injuring himself. The *head need not be kept at a low level*; *indeed this is sometimes a disadvantage*, since stretching of the neck muscles causes discomfort.

When prognosis is uncertain in the early stages, drugs should be given sparingly and it is safer to give small amounts frequently than one large initial dose. A routine which I have found useful and safe is as follows: First, soluble luminal 0.2 gm. (3 grains) is given intravenously, followed by chloral hydrate 0.65 gm. (10 grains) and sodium bromide 0.65 gm. (10 grains) by mouth. When a patient will not swallow, double doses of chloral and bromide are given per rectum. The chloral and bromide may be repeated in two hours and afterwards at lengthening intervals until reasonable rest is procured. Paraldehyde is also an excellent drug, and 16 c.c. (4 drachms) may be given per rectum instead of the chloral and bromide. Morphine is rarely needed, but 16 mg. (¼ grain) in combination with luminal will often give a complete night's rest. The principle to be observed in the administration of drugs is to give the minimal amount which will produce the desired effect; to give more is dangerous and to give less is useless. Constant supervision of drug administration is therefore essential and should be the personal responsibility of the surgeon himself.

Feeding

When patients are unable to swallow, feeding should be effected through a tube passed through the nose into the stomach, the tube being fixed to the cheek by adhesive plaster.

The amount of dehydration necessary to prevent cerebral oedema should be considered when fluids are given and only the minimum quantity necessary for bodily needs should be allowed in the first twenty-four hours. One-ounce drinks of glucose in water are all that is necessary and the quantity may be increased on the second day if the patient's condition improves.

When there is considerable cerebrospinal fluid pressure associated with deep unconsciousness 2 pints daily only should be given this is the minimal quantity and should be increased as soon as the patient s condition warrants it On the second day milk drinks may alternate with the glucose fluid

It is obviously impossible to give fixed details of feeding and each case must be treated indi idually but by the third day some more solid foods are necessary—junket egg custards, milk puddings and meat jellies all being useful protein-containing foods

The Bowels

Incontinence may occur if aperients are given to an unconscious or semiconscious patient this can be avoided by the administration of a mixture containing bismuth and opium Enemata to empty the bowel are in my opinion a better method than the administration of drugs such as magnesium sulphate Cathartics such as calomel are best a oided, since they often produce colic with resulting restlessness.

The Bladder

Incontinence sometimes occurs and in such case frequent changing of the bed linen is necessary to avoid ulceration of the skin. When retention occurs it is often due to apraxia, the patient not being able to empty his bladder because he does not know what to do Catheterisation is then essential otherwise restlessness will increase When the stage of semiconsciousness is reached a bedpan or bottle according to sex is placed in position and the patient asked to pass water If this measure is successful the procedure should be repeated at three-hourly intervals until consciousness returns

The Skin, Mouth and Eyes

Constant care is needed if the skin is not to ulcerate In cases of extreme restlessness it is best to pad the knees, elbows and heels with bandages to a oid abrasions. The mouth should be swabbed out regularly with a mixture of glycerine and borax water If a patient clenches his jaws, metal forceps should not be used—a suitable instrument is a strong pencil of wood wrapped in wool The eyes should be bathed with boracic lotion

Temperature

In order to treat shock it is usual to place a patient in a radiant heat cradle Unless the temperature is taken at regular intervals however complications such as hyperthermia may result since the thermo-regulating centres are often temporarily inactive with the result that the body is apt to assume the temperature of its environment. Should the temperature rise 2 F or more, treatment consists in tepid sponging if more vigorous measures are necessary cold packs may be applied with intra enous injections of aspirin 1 3 gm (20 grains) A rise in temperature often oc urs in ases of subarachnoid haemorrhage owing to absorption of blood A rise in temperature may be the only sign of the development of hypostatic pneumonia The nursing staff should be on the alert for the onset of a rigor which may be the first ign of meningitis In all these cases chemotherapy should

be instituted at once. Hyperthermia is often the cause of death in severe intrinsic injuries, particularly of the hypothalamus, and there is no effective treatment.

MANAGEMENT OF THE SECONDARY PATHOLOGICAL MANIFESTATIONS

Unless they are grave, injuries elsewhere in the body should in the first instance receive no more than the minimal treatment that does not prejudice their final repair. It is, moreover, wrong to excise and repair a wound of the head with the object of preventing infection until the factor of concussion has been assessed and treated. In cases of known blood loss, or when the blood pressure remains below normal in spite of the general measures indicated previously, whole blood transfusions should be given. It is, however, important not to oversaturate the body with fluid. Intravenous normal saline is contraindicated as it is apt to produce cerebral oedema and to aggravate the cerebral damage.

LUMBAR PUNCTURE

The diagnosis of the nature and site of secondary pathological lesions is a difficult problem; even those who are neurologically trained and who have a special knowledge of the pathology of cerebral trauma are often unable to visualise the nature of the pathological processes that are going on in the head.

When a patient is obviously recovering consciousness, no surgical treatment is necessary. If a patient remains critically ill in spite of medical measures, and if there are no frank neurological signs to indicate exploration of the head, the only treatment consists in ensuring that the intracranial pressures are kept within normal limits. This can best be done by lumbar puncture, manometry, and withdrawal of the cerebrospinal fluid.

Dehydration by hypertonic saline solution has little or no place in the treatment of a head injury in its acute phases. When cerebrospinal fluid pressure is below normal in spite of a normal blood-pressure, intravenous hypotonic saline is indicated.

A general anaesthetic must never be given in order to quiet a restless patient so that the cerebrospinal fluid pressures can be measured, for anaesthesia not only alters the pressures but also jeopardises the patient's life. As a rule, no surgical intervention is necessary within the first twelve hours of the infliction of a head injury; after this, puncture and drainage should be carried out every six hours until the pressure remains within normal limits. Punctures are carried out with the patient in the lateral position with the head on the same level as the buttocks. Normal pressure lies between 50 and 150 mm. of cerebrospinal fluid; when a pressure reading is above 150 mm., sufficient cerebrospinal fluid to bring the reading down to 50 mm. is withdrawn. The advantages of a puncture far outweigh the dangers of producing a pressure cone or of breaking a needle in a restless patient's back.

When it is found impossible safely to make a lumbar puncture without anaesthesia, I make an inspection hole in the head under a local anaesthetic and drain the cerebrospinal fluid through a small drainage tube for thirty-six hours. In this case the patient can be controlled by tethering the trunk and limbs to the operating table by the method to be illustrated later. Intravenous hypotonic saline therapy is

reserved for secondary developments of cerebral oedema that lead to delayed headaches and confusion

SURGICAL EXPLORATION OF THE INTRACRANIAL CAVITY

Indications

The absolute indications for surgical exploration of the intracranial cavity are as follows:

(a) A latent interval must always be regarded as indicating a surface haemorrhage that is amenable to surgical treatment. If the position of the presumed clot cannot be determined on neurological grounds it must be sought for by making a series of inspection holes on both sides of the head.
(b) Retrogression following a period of improvement which cannot be controlled by spinal drainage or by intravenous dehydration.
(c) Delayed decerebrate rigidity.
(d) A fixed dilated pupil.
(e) Prolonged unconsciousness associated with persistently high cerebrospinal fluid pressure.

Anaesthesia

Local Anaesthesia. When possible, operations on closed head injuries should be carried out under local anaesthesia (Figs. 1 to 4). One per cent novocain solution containing 5 drops of adrenaline to each 100 c.c. is used. Two to three hundred

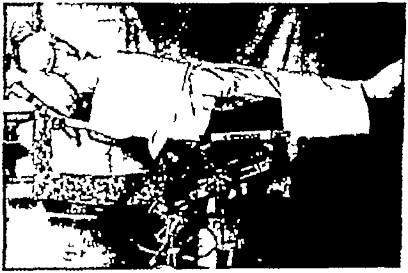


Fig. 1. The positioning of the patient and the tethering of his limbs on the operating table for a decompression under local anaesthesia.

cubic centimetres may be safely injected. The line of the incision is injected until a definite mound is raised. The needle is then introduced at right angles at intervals of 1 inch and the pericranium injected. Special care is taken thoroughly to inject the base of the flap and to infiltrate the pericranium and any deeply lying muscles.

Fig. 2. The overhead table in position, with the anaesthetist comfortably seated in position to ontrol the patient jaw and t ensure a free airway

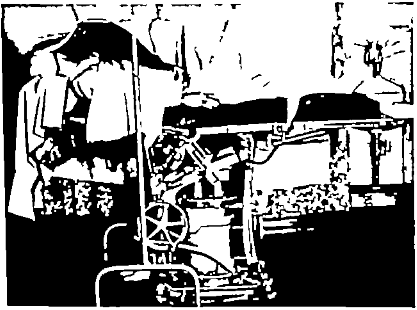


Fig 3 A side view showing the way the tow ls are draped from the patient head across the *overhead table leaving the face free*

Special injections may be necessary according to the nerve supplies of special regions In every case satisfactory anaesthesia can be obtained if care is taken The administration of adrenaline novocain solution has the further advantage of lessen-

ing the bleeding from the skin and muscles Local anaesthesia is essential to minimise shock even when a patient is so deeply unconscious that he appears insensitive to pain If the wound is not anaesthetic when compression of the brain is relieved, a patient may wake and begin to feel pain again with resulting restlessness

Supplemental Pentothal If after the start of an operation under local anaesthesia, a patient becomes uncontrollably and dangerously restless he can be quickly and easily quieted by intravenous pentothal This drug is also useful at the end of an operation to facilitate sewing up when the patient is regaining consciousness and feeling pain

Intratracheal Anaesthesia Intratracheal intubation is essential when a general anaesthetic is necessary because of restlessness or of bruising or laceration of the scalp or because injuries elsewhere in the body need treatment. It is useful to smear

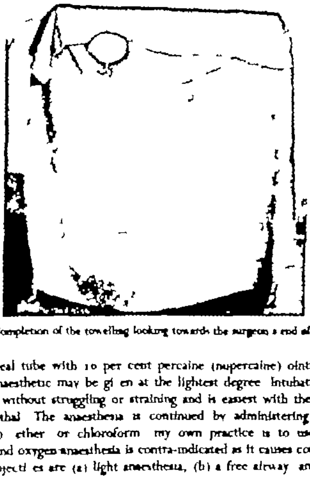


Fig 4 Completion of the towelling looking towards the surgeon s end of the table

the intratracheal tube with 10 per cent percaine (nupercaine) ointment so that the general anaesthetic may be gi en at the lightest degree Intubation should be accomplished without struggling or straining and is easiest with the aid of intra venous pentothal The anaesthesia is continued by administering trilene (trichlorethylene) ether or chloroform my own practice is to use trilene and oxygen. Gas and oxygen anaesthesia is contra-indicated as it causes congestion The three main objecti es are (a) light anaesthesia, (b) a free airway and (c) perfect oxygenation

Basal Anaesthesia Basal anaesthesia with drugs like avertin and morphine should be given only under special circumstances Atropine may be given freely at any stage of the operati e procedure

General Theatre Technique

Without adequately planned theatre technique mere manipulative skill will not be sufficient to overcome the difficulties that might be met with on opening a head Indeed correct positioning of the patient on the operating table and skilled towelling

Fig 5 The general theatre outlay seen from the front

of the operative field are two of the fundamental principles of neurological surgery Serious bleeding must always be expected and means for dealing with it must always be at hand In view of its importance theatre technique will be described in some detail (See Figs 5 to 8)

Fig 6 The operating team in position.

The Scalp Except for the trimming of a simple wound the whole of the scalp apart from the eyebrows should be shaved when an operation on the head is contemplated The skin is washed with soap and water swabbed with dettol (chlor

oxylenol) and wrapped in a sterile compress Iodine and spirit are undesirable as they scale or burn the skin The line of the incision is marked out with methylene blue In order to prevent unnecessary or dangerous blood loss each side of the incision is compressed by the finger tips of two assistants who pull the wound apart

Fig. 7 The operating table as seen from the back, with the anaesthetist and attendant nurse in position.

as the galea is incised. Artery forceps are applied to the galea at ½-inch intervals and thrown backwards to evert the edges of the wound Swabs are placed between the skin and the artery forceps to protect the skin should the forceps be inadver

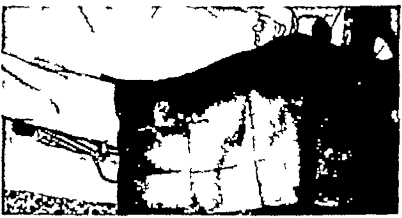


Fig. 8 In injuries of the parasagittal veins the head should be erected, thus ensuring minimal congestion of the veins and of the parasagittal ones.

tently touched with the diathermy electrode When a series of forceps are used, they are best arranged in neat bundles by tying their handles together and pinning them to the towels In compound wounds excisions of the skin should be very sparingly carried out indeed it is my practice to remove only those parts which

are thought to be non-viable. Only bruised tags are nipped away, the rest of the skin being scraped or picked clean. (See Fig. 9.)

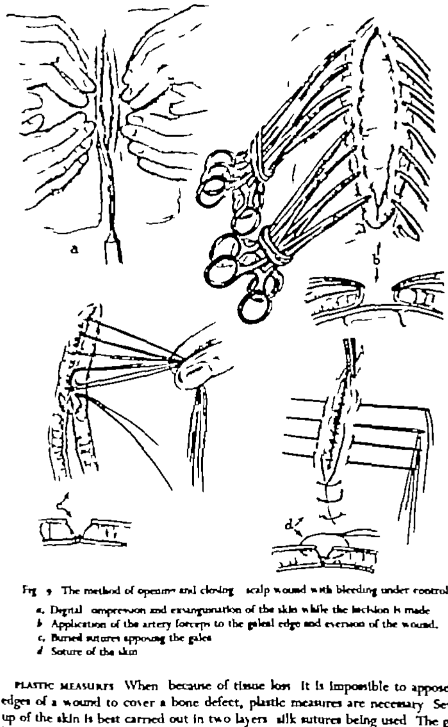


Fig. 9. The method of opening and closing a scalp wound with bleeding under control.

a, Digital compression and exsanguination of the skin while the incision is made.
b, Application of the artery forceps to the galeal edge and eversion of the wound.
c, Buried sutures apposing the galea.
d, Suture of the skin.

PLASTIC MEASURES When, because of tissue loss, it is impossible to appose the edges of a wound to cover a bone defect, plastic measures are necessary. Sewing up of the skin is best carried out in two layers, silk sutures being used. The galeal layer is buried and the knots of these sutures should, therefore, be cut extremely

short otherwise they will protrude and prevent healing or irritate the deep tissues. As a rule if the scalp edges can be firmly drawn together by galeal sutures alone tension is not too great to prevent healing It is useless forcibly to drag the skin edges together when there has been loss of tissue as this will only lead to exsanguination and sloughing

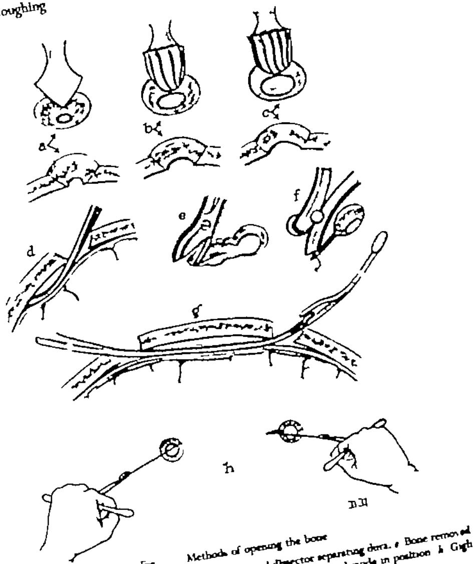


Fig Methods of opening the bone

Perforator *b* Burr No Burr No 2 *d* Curved director separating dura. *e* Bone removed with nibbling forceps *f* Linear cut with DeVilbiss forceps *g* Saw and guide in position *h* Gigli saw attached to needle

Opening the Bone The bone may be opened either with a trephine or by means of a brace and bit perforator and burrs The advantage of removing a trephine disc is that the bone can be replaced should further manipulations prove unnecessary A trephine end can always be fitted to a Hudson s brace, thus avoiding the heavy labour of using this instrument on a hand grip The various methods of opening the

bone are illustrated in the accompanying diagrams (Fig 10) A brace and bit must always be held so firmly that even though it should slip it will not penetrate the brain

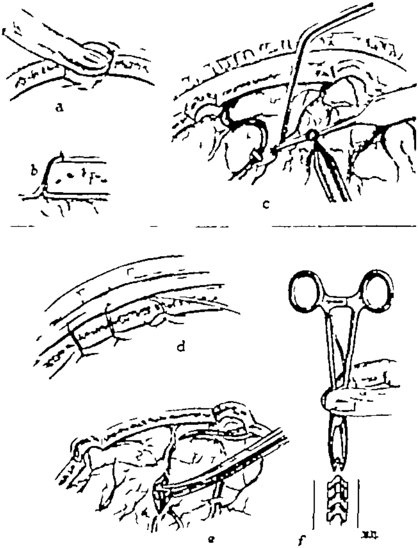


Fig The methods of controlling bleeding

Control of bleeding from the diploic channel by sealing with Horsley w x.
b Hitch stitch.
Diathermy coagulation of ortic l vessel.
d Dura stitched to galea (hitch stitch)
Occlusion of vessel by silver clip.
f Mackenzie silver forcep and stand

Control of Bleeding A coagulating current is used for sealing veins or small arteries on the dura, in the muscle or in the brain Vessels in the skin, however should never be sealed by coagulation as this would lead to necrosis of the skin Bleeding

from large arteries is best controlled by compressing the vessel with a silver clip applied in a special holder (Fig 11) Haemorrhage from the bone is readily controlled by pressing Horsley s wax into the bleeding channels Muscle grafts are of value in the repair of tears in the dural venous sinuses they are also useful for

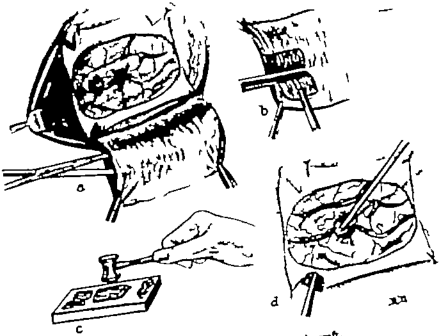


Fig 2 Bleeding ontrol by muscle graft.
a Removal of temporal muscle stamp.
b Hammering of the muscle graft
c Application of the graft to bleeding ortical essel

controlling persistent bleedings from the surface of the brain or from the dura when other methods ha e failed A piece of muscle cut from the temporalis and pressed into a thin sheet will stick like a postage stamp when placed in position (Fig 12) The stitching of the dura to the pericranium at the edges of a wound will often prevent the formation of a post operati e lot

SUBTEMPORAL DECOMPRESSION

Definition

The word decompression implies that a piece of the cal arium has been removed and that the underlying dura mater has been widely opened to allow the brain to bulge thereby reducing the intracranial pressure Often the word is loosely used to mean subtemporal exploration

Decompression must be arried out only under the fleshy bellies of ither the temporal or oc ipital muscles

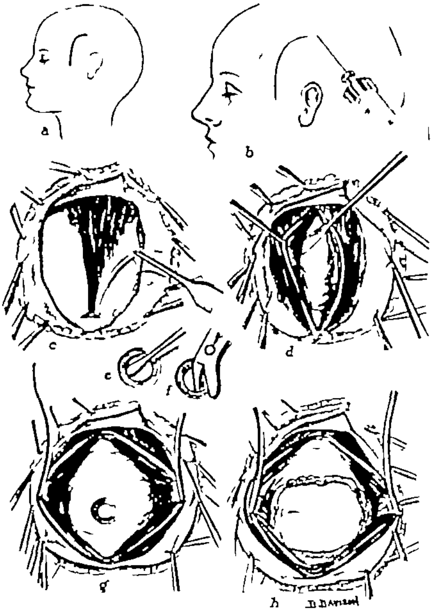
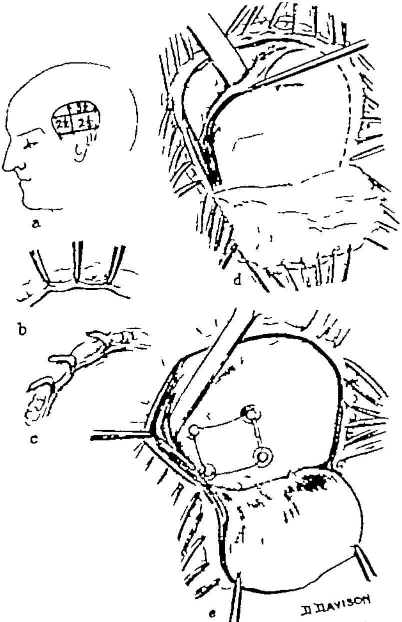


Fig. 3 Subtemporal exploration by muscle split.

Line of incision
b Zone of anaesthesia
Separation of temporal fascia from temporal muscle
d Immobilisation of temporal muscle
Separation of dura from bone
f Removal of bone by nibbling
g Exposure of bone
h Exposure of the dura and middle meningeal vessels.



F 4 Subtemporal exploration by muscle slide

L ne of sk ncision and zone of anaesthesia

b Haemos by artery forceps

A ma method of haemostasis by Michel clips

d Subperi al separation of the temporal muscle with its overlying fascia

E ur he bone and re of proposed bone removal

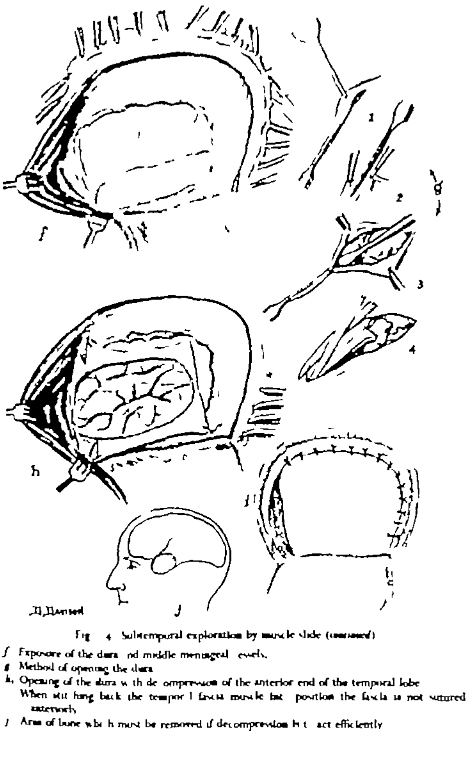


Fig. 4. Subtemporal exploration by muscle slide (continued)

f Exposure of the dura and middle meningeal vessels.

g Method of opening the dura.

h Opening of the dura with decompression of the anterior end of the temporal lobe. When returning back the temporal fascia-muscle flap to position the fascia is not sutured anteriorly.

j Area of bone which must be removed if decompression is to act efficiently.

Localisation of the Site of the Haemorrhage

When a patient becomes unconscious following a lucid interval a diagnosis must be made of a surface haemorrhage which is amenable to surgical treatment In the majority of such cases the march of the neurological changes signs of local bruising, or x ray e idence of a fracture crossing a middle meningeal groove will make it possible to localise the site of the haemorrhage In the remainder of cases the site of the haemorrhage will be unknown the haemorrhage must then be localised by means of inspection holes and before the search is abandoned at least two of these should be made on each side of the head one at the pterion and one at the parietal eminence

An inspection hole should always be so placed that should a haemorrhage be discovered the hole can be utilised in a wider exposure Care must also be taken that the incision for an inspection hole does not prejudice any future reopening that may be necessary for repair of the skull A burr hole may conveniently be made along any of the limbs of a formal decompression

Removal of the Clot

Before operation for a middle meningeal haemorrhage a blood drip should be set up by an assistant The finding of the clot and the opening of the bone should be carried out as expeditiously as is compatible with gentle handling Once the clot is found the bone over it should be widely removed and when this is accomplished there is not the same necessity for speed Indeed it is better to wait for a few moments at this stage to allow the circulation of the brain to readjust itself to the new conditions The blood clot should be slowly removed piecemeal from above downwards by a combination of scooping and suction finger removal is contra-indicated as this may add further compression to the already embarrassed cerebral circulation

Control of Bleeding

In some cases the source of the bleeding will be obvious on removal of the clot Usually the bleeding results from a rupture of the middle meningeal vessels and is quickly controlled by diathermy coagulation

When profuse bleeding comes from the top or from the back of the wound a dural enous sinus has probably been torn this is best controlled by packing muscle grafts towards the bleeding point between the dura and the bone The dura is then hitched up to the galea at the periphery of the wound as shown by the stitches illustrated in Fig 9

Bleeding oc asionally occurs from diploic essels and can be controlled by pressing beeswax into the bone channels or along the fracture lines

Subdural Clots

Subdural lot an be seen by the naked eye showing through the dura as black or bluish ta n When there is doubt about the presence of such a clot, the dura should be incised and the subdural space examined When a clot is discovered it should be acuated and the space drained It is rarely profitable to search for the bleeding essel but should it be obvious t should of course be sealed

When a firm diagnosis of surface clot has been made and none can be found, a wide subdural decompression should be made on the right side. Exploration of the brain itself for the removal of an intracerebral haemorrhage is rarely indicated.

COMPOUND WOUNDS OF THE HEAD

There are two varieties of compound wound of the head: (a) those resulting from fracture of the basal air sinuses with tearing of the overlying dura, and (b) those occurring on the vault of the head. Since the surgery of internal compounding is so complex that it must necessarily lie in the hands of the neurological surgeon, the following advice is limited to the treatment of compound wounds of the vault.

Preparation of Scalp

Except in small and obviously superficial wounds the whole of the scalp should be shaved. For any procedure other than the repair of simple wounds a blood drip should be set up at the beginning of an operation. In a major operation the edges of the wound are scrubbed clean with a sterile nail brush and sterile soap and water. Using a scalpel and forceps that can be discarded when the depths of the wound are approached, the skin edges are excised. Skin excision should be sparingly carried out; indeed it is my practice to remove only those parts of the skin that are thought to be non-viable; the other parts are scraped, picked or nipped clean. The contaminated instruments are then discarded and the operating gloves changed if necessary.

Exposure of Deeper Structures. Plastic Measures

The depths of the wound are then inspected. If necessary, the wound is enlarged so that the deeper structures can be properly exposed. In enlarging the wound the blood supply to the skin flap must be remembered, as also the possible necessity of reopening the wound at a later date for repair of the skull. When plastic measures are necessary these should be carried out boldly. An essential principle is that a bone defect should be covered by a thick piece of skin and that any scar that happens to cross it should be firmly healed and of full thickness.

Management of Bony Fragments

It is essential that the whole area of the depressed fragment of bone should be exposed. From the local appearances it usually can easily be decided whether the bony fragments can be raised without difficulty, or whether a fragment will have first to be loosened by making a burr hole in healthy bone and approaching the fracture from the periphery, or whether the whole depressed fragment should be removed by block dissection.

Those pieces or edges of bone that are thought to be contaminated are removed or excised. When not thought to be contaminated, pieces of bone may be replaced in position even though they are completely loose. When a defect in bone is inevitable, its shape should be fashioned with the possibility of future repair in mind.

Management of Dural Tears

Tears in the dura should be uncovered until the whole length of the opening can be seen and the brain within explored if necessary. Usually the edges of a dural

tear are puffy and fleshy this means that swollen brain tissue has herniated through and become attached to the dural edge by sticky exudations In this puffy mass lie large cortical essels and it is at this stage that dangerous bleeding difficult to control may be started if great care is not taken The best method is to open the dura a short distance from the periphery of the tear and cut into the opening Only the most limited trimming of the dura mater is permissible if attempts are to be made later to draw the membrane together When the dura will not easily pull together It should be repaired with a sheet of fascia cut from a neighbouring muscle or from over a neighbouring bone In severe losses a sheet of fascia lata should be cut from the thigh

Débridement of the Brain

On débridement of the brain care must be taken not to damage healthy brain tissue All dead and foreign tissue must be remo ed and this is best accomplished by gentle suction In particular bone fragments embedded in the brain tissue must be carefully excised and this is one of the reasons why careful pre-operative x ray studies of a compound depressed fracture of the skull should be made

Special Points in Technique

When it is judged that the brain is under such great pressure that it will seriously herniate when the dura is opened the intracranial pressure should be lowered by lumbar puncture and drainage of the cerebrospinal fluid Therefore when a patient with a compound wound is also suffering from concussion he should be so placed on the table that lumbar puncture can be carried out if necessary

When a depressed fracture overlies the parasagittal sinus and when there is a danger that the sinus is torn the head should be so placed on the table that the torn part occupies the highest point of the operative field the head being higher than the rest of the body

Bleeding from the ears should be regarded as a sign of a compound fracture of the skull It indicates that chemotherapy is necessary as a prophylactic measure and the ear should be covered with a sterile swab fixed into position with elastoplast strapping Syringing or any kind of local treatment is contra-indicated. Whenever there is a possibility of intracranial infection developing chemotherapy should be started as a prophylactic measure and continued until the danger of infection has passed

CHAPTER 2

Spinal Tumours

LAMBERT ROGERS

There can be few greater satisfactions in surgery than that which follows operation on a patient who has been stricken with the palsy and who recovers so completely as to be able to take up his bed and walk. A large percentage of spinal cord tumours which by compressing the cord cause paraplegia and incontinence can be safely and completely removed without harm to the cord and provided this removal is carried out before conduction in the cord is irreparably destroyed the results are excellent

HISTORICAL

From time to time operations for the removal of spinal tumours must have been contemplated by thoughtful surgeons in different countries and in 1873 Leyden in Strasbourg had actually planned though he failed to carry out, an operation for a tumour which he had localised successfully It was just over sixty years ago in 1887 that the first spinal cord tumour was removed from a living patient The operation was performed at the National Hospital for Nervous Diseases in London by Victor Horsley assisted by Charles Ballance The patient, an Army officer aged 42 had spastic paraplegia in extension the result of cord compression by a tumour in the upper thoracic region After its removal he made a complete recovery and a few months later was able to work sixteen hours a day He remained well up to the time of his death from another cause twenty years later The tumour (Fig 15) was described at the time as a myxoma in part cystic but we should almost certainly now classify it as a neurinoma It was in the Hunterian museum of the Royal College of Surgeons of England until May 10 1941 when it was destroyed along with other specimens by a high explosive bomb dropped from an enemy aircraft raiding London

CLASSIFICATION

According to their pathology spinal tumours may be classified as benign or malignant primary or secondary and anatomically as extra or intra thecal and

extra or intra medullary The commonest spinal tumour is intrathecal and extra-medullary and is usually capable of complete removal It is either a neurinoma

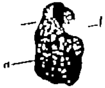


Fig 5 Photograph of the first spinal tumour to be successfully removed, the natural size. This tumour was Specimen 5063 in the Museum of the Royal College of Surgeons of England but was destroyed by enemy action on May 0 94 when the College received direct hit by high explosi bomb dropped from an enemy aircraft The tumour w removed on June 9 887 by Sir Victor Horsley t the National Hospital Queen Square from man aged 42 who made a omplet recovery from his paraplegia and lived for twenty years afterwards.

Lobulated surface of solid portion of tumour which produced an excavation of the cord.

b Open ca ty in the tumour this cavity being ruptured during the removal of the mass.

Fibrous capsule forming part of the inner wall of the cystic avity

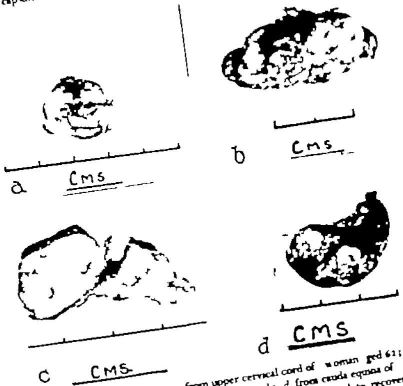


Fig Spinal ord neurinomata, from upper cervical cord of woman ged 61; *b* and from midthorac reg on of women aged 23 and 67 respectively *d* from cauda equina of man aged 44. Tumours *b* and *d* w re in part ystic All these patients made complete recoveries following removal of he tumours

(neurl n ma (Figs 6 7) grow ng from the sheath of a spinal nerve or a meningioma ar n the men nges (Figs 18 9)

PROGNOSIS

For the benign intrathecal tumour which has compressed the cord prognosis may be regarded from two points of view namely immediate i e as to return of

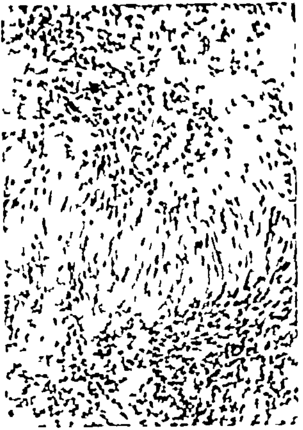


Fig 7 Microscopical appearance of spinal neurinoma

Fig 8 Spinal cord meningioma with attached area of dura mater removed along with it The tumour is from the thoracic region of woman aged 55 who made complete recovery following its removal

conduction in the cord with restoration of function and remote i e in regard to the liability to local recurrence of the tumour or later complications from it It is well known that the divided human spinal cord is irreparable Cobb Pilcher puts

it graphically Like Humpty Dumpty it cannot be put together again It is surprising, however to what an extent the cord may be compressed by a tumour particularly in a young subject, and yet regain its function on relief of compression It may appear flattened like a piece of tape at the site from which the tumour has been remo ed and yet be capable of complete recovery This recovery of conduction is very much a question of blood supply and no doubt this is the reason why such gratifying restoration is seen in young subjects Other factors being equal the younger the subject the better the prognosis If removal of the tumour takes place with the patient in spastic paraplegia in extension recovery is usually good and the same applies though with some reservation if the spasticity is in flexion. It has been

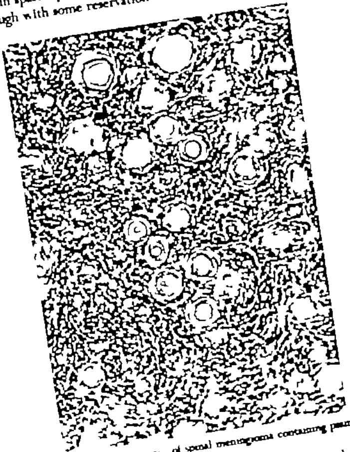


Fig 9 Macroscopical appearanc of spinal meningioma containing psammoma bodies

said that f paraplegia is flaccid conduction is lost irretrievably but this is not true as I ha e had a patient a woman aged 42 who reco ered the complete use of her limbs after the onset of flaccidity and in the presence of large pressure sores Her re o ry was so complete that she has since married It would be true to say h we r that if flac idity has been present for any length of time recovery is unl k l

A regards any liability to recurrence the neurinoma carries an excellent prog-

The ne rinoma sometimes take the form of dumb bell or hour glass tumour in which the intr spinal nd xtraspinal parts are onnected by narrow isthmus through the intervertebral for h h m ime be omes enlarged In the rvical region the extraspinal part may be ap paren ur in the post rior triangle of the ne k

nosis. It is capable of complete removal and when so removed does not recur nor does it produce late complications. The meningioma may recur if any of its cells of origin remain in association with the overlying meninges to which the tumour is adherent. To prevent such recurrence it is necessary to remove this adherent meningeal area along with the tumour (Fig. 18). The defect in the meninges can be made good with a piece of one of the fibrin products, gelfoam.

SYMPTOMS AND COURSE

The course of a spinal cord tumour is a progressive one, not characterised by the periods of remission so frequently seen in cases of disseminated sclerosis. It was aptly described by the late Sir Percy Sargent as "slow but remorseless." The typical clinical picture is one of spastic paraplegia, motor and sensory impairment being present below a particular segmental level, and the deep reflexes exaggerated.

Pain is usual and may be radicular in type but it is not invariable and some spinal cord tumours run a painless course.

Some spinal tumours produce intense root pain but such is not necessarily characteristic of the neurinomata, as one or more roots may be involved by the growth of a meningioma, and I have known intense sciatica caused in this way by a meningioma adherent to the root of the cauda equina.

The earliest sign of a spinal tumour is often a subjective temperature change in one foot, spreading to the leg, followed by weakness.

The signs of gradually progressive cord compression pass through three phases: first spastic paraplegia in extension, next spastic paraplegia in flexion, and finally flaccidity. After the relief of compression, recovery occurs in the reverse order to the changes produced by compression, i.e., spastic paraplegia in flexion is followed by spastic paraplegia in extension and then the hypertonus passes off and normal movement becomes re-established.

DIAGNOSIS

The diagnosis may be strongly suspected from the history and clinical picture which has already been outlined. Confirmation may be obtained by investigation of the state of the subarachnoid space around the cord in order to ascertain whether "spinal block" is present or not. Spinal block indicates the presence of a space occupying lesion as the cause of the interrupted conduction in the cord, and is usually therefore an indication for operation.

Investigation of Subarachnoid Space

This is carried out by performing lumbar puncture with the patient lying in the lateral position with the sagittal suture in the plane of the spinal column. The pressure of the fluid in the lumbar pond is then measured and jugular compression performed to test for the presence or absence of Queckenstedt's phenomenon or its modification (Fig. 19).

Chemical and cytological examination of the fluid is undertaken. Stagnation may be shown by a normal number of cells with an increase in protein content. In extreme cases the fluid may be yellow and may clot in the manometer.

Complete or partial "spinal block" may be thus determined and further confirmation obtained by myelography.

Myelography Except in lesions low in the lumbar region the opaque medium (e g lipiodol myodil pantopaque) should be introduced by cisternal

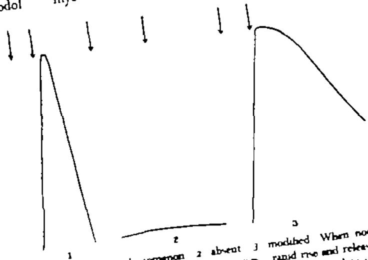


Fig 2 1 Queckenstedt phenomenon 2 absent 3 modified When normally present, pressure on the jugular veins t the root of the neck auses rapid rise and release of pressure a rapid fall of erebrospinal fluid pressure in the lumbar pond (1) In complete spinal block this phenomenon bsent (2) In partial spinal block t may be modified (3) by plateau type of urv the obstruction acting as ball valv raped rise in jugular compression and a delayed fall on ts release The arrow mark the onset and elease of jugular compression.

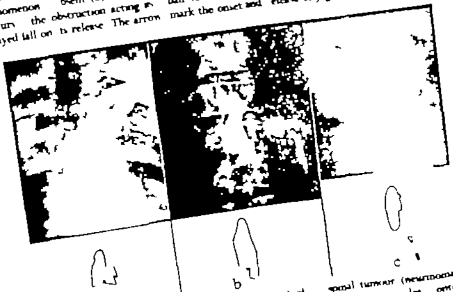


Fig 3 T pical myelograms (ist mal introduction) of spinal tumour (neurinoma, man aged 33) b intervertebral disc lesion—a mass entral protrusion of the ucles ontent d the disc (man aged 4), and meningitis irumscripta serosa (man aged 45) Not the appe nc of the lower surfac of he blob in ach ase

puncture A hold-up of the opaque material onfirms the nature of spinal block, but show cise level of d may also It nature e g in tumo ower part of h is onc

In a ase of ara hnoI Itis wl Ich ma closely imulate a plnal tumour the I lob Is convex I low (Fig 21)

Differential Diagnosis

The investigation f the pinal ubarachno id pace by lumbar manometry chemical examination of the fl i l and if indicated myelographs will differentiate compres ion of the c rd and pace-occupying lesi ns in the c r l from those causes of interference with c nduction in the c rd uch as multiple scleros amy trophic lateral scleros and the various lemy linating iseases and als from the acute irus and vascular lesions

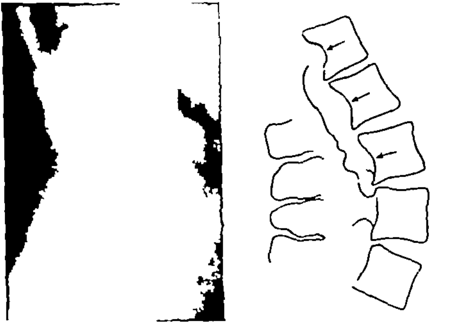


Fig 22 X ray appearanc of the lateral aspect of the lower thoracic and lumbar parts of the spinal olumn showin oncavities produced on the back of these vertebrae by ascular spinal tumour—a large haemangioma woman aged 35 Simila concavities are produced on the front of ertebral bodies by an aneurysm.

T bercle may be e ident from the x ray appearances of the bone but occasionally this condition closely simulates spinal tumour and may be first evident as compression with no apparent bony changes

A massive central herniation of the nucleus pulposus of an intervertebral disc may closely mimic a spinal cord tumour and for that matter acts as one and equally calls for removal by operation

Metastatic tumours can usually be differentiated from true cord tumours by the fact that the onset of signs and symptoms in the former is usually rapid and in some cases the primary neoplasm is apparent e g in the thyroid testis breast lungs or kidney Other occasional causes of compression are abscesses and cysts of the latter hydatids somet mes occur in the spine and are extradural

Paget's disease may also be a cause of cord compression and here the diagnosis is obvious from the x ray appearances of the bone

Primary extradural tumours may arise in the *bone* or may be *lipomata* or *haemangiomata* The blood vessel tumours may produce uniform erosion of the backs of the vertebral bodies comparable with that produced by an aortic aneurysm on the fronts of the bodies with which it is in contact (Fig 22)

Intramedullary tumours and *syringomyelia* may produce similar clinical pictures an outstanding feature of which is sensory dissociation In syringomyelia spinal block occurs only if the cysts are large ones and sufficiently distended to fill the canal and compress the cord, in which case they are better opened This is the only circumstance in which surgery is likely to be of value in syringomyelia.

It is sometimes possible to distinguish between intramedullary and extramedullary tumours from the history and clinical pictures because as Elsberg has pointed out pressure on the long conducting tracts from outside the cord affects first those from the feet and legs so that the progressive march of an extramedullary tumour produces sensory and motor changes first in the toes and feet next in the legs and then the thighs whereas an intramedullary tumour may manifest itself by initial weakness of the thigh or leg muscles

TREATMENT

The treatment of operable tumours of the spine is by an approach through the neural arches i e the operation of laminectomy If carefully performed so that the erector spinae muscle masses are not damaged and the lateral extent of the removal of the laminae does not damage the pedicles and intervertebral joints the operation does not subsequently weaken the spinal column even if it has been extensive and a number of laminae have been removed

The level at which laminectomy is performed and the number of laminae which it is necessary to remove depend on the position and extent of the tumour Its position is indicated precisely by myelography If localisation is made on clinical grounds alone it must be remembered that there is an increasing discrepancy between the spinal segments and the vertebral bodies to which they are related as we descend the column A sound working rule to ascertain this difference is to allow a discrepancy of one vertebra in the upper cervical region, two in the lower cervical three in the upper thoracic and four in the lower thoracic region e.g a sensory level at D 10 would indicate a tumour at D 6

At operation the tendency is to perform the laminectomy at too low a site This happened in the classical case of the first successful removal performed by Horsley in 1887 There was no tumour found and Charles Ballance who was assisting Horsley at the time and was also Demonstrator of Anatomy at St Thomas's, knew that the segments were higher in the cord in relation to the vertebral bodies than was then realised. He urged Horsley to remove a lamina higher up and the lower part of the tumour which had not at first been revealed, was then exposed

The relationship of the vertebral bodies to the segments in the cord is somewhat variable so that even in cases in which there is a very definite sensory localisation it is advisable to perform cisternal myelography before operating to remove the tumour The precise level will thereby be ascertained.

THE OPERATION

Anaesthetic

Laminectomy may be performed under local infiltration analgesia (1 per cent procaine with adrenaline 5 minims to each ounce) but general anaesthesia is the choice in most cases. Intubation after pentothal induction and nitrous oxide with oxygen and chloroform has proved highly satisfactory.

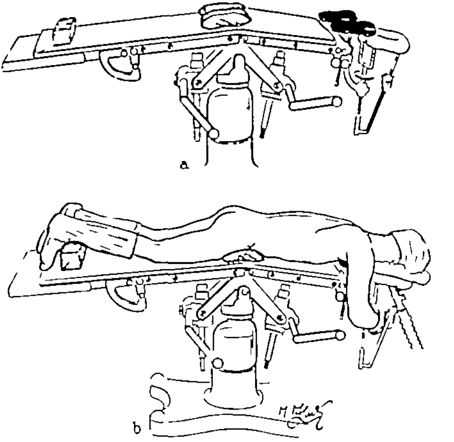


Fig. 23

Operating table in position for laminectomy in thoracic region.

b Patient in position on table for laminectomy in thoracic region. Note the position of shoulder rest to keep chest clear of operating table and of sandbags under the iliac crest in order to keep pressure off the abdomen and avoid distention of the spinal veins.

Position of Patient

Whether the operation is to be on the cervical, thoracic or lumbar parts of the spine, it is best carried out with the patient fully prone, the head supported on an outrigger and the chest kept clear of the table by shoulder supports so that respiration will not be embarrassed by pressure on it. If the laminectomy is to be performed on the thoracic or lumbar regions, the abdomen is kept clear of the table by means of sandbags placed under the anterior superior iliac spines (Fig. 23). By this means pressure on the abdomen and consequent congestion of the spinal veins are avoided.

Incision

The incision is made along the line of the spinous processes (Fig 24) Curved incisions and flap types of operation are avoided because the blood supply of the skin of the back is not as abundant as it is in some regions of the body and the

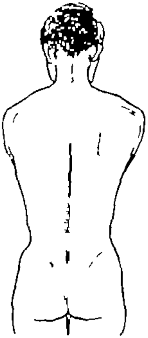


Fig 24 Line of incision for thoracic laminectomy Flap types of incision are to be avoided because of the relatively poor blood supply of the skin of the back.

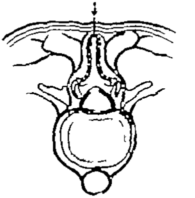


Fig 25 Diagram t show line of incision and plane of separation of the erector spinae muscle mass so t turn t outwards w thout interfering w th its blood supply

blood supply to the edges of the wound is maximal if this wound is a median longitudinal one Furthermore it is always possible to extend a longitudinal incision should this be necessary

Haemostats pick up any essels in the subcutaneous tissue which may bleed Skin

towel are attached to the wound edges and used to shut off the skin of the back from the operation area. The aponeurosis is next divided in the line of the skin incision and using both scalpel cutting endotherms and a broad bladed osteotome

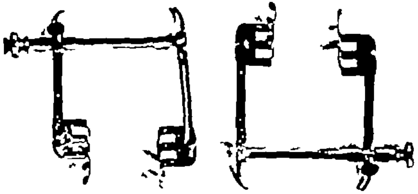


Fig. 26 Laminectomy retractors, author's pattern

the erector spinae muscle mass is separated from the spinous processes and laminae on one side (Fig. 25). As it is separated gauze swabs are pressed into the gap produced by the separation. These swabs control bleeding and are left in position

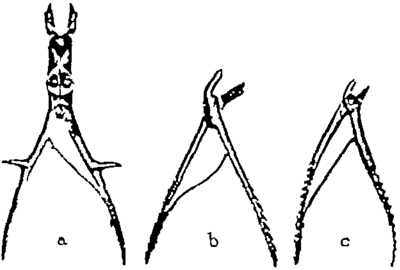


Fig. 27 Instruments used for cutting and removing the bony coverings

a Bone-cutting forceps for spinous processes
b Nibbling forceps for neural arches

while the muscle mass on the other side is likewise turned out of the post-vertebral groove by a similar subperiostial manoeuvre, swabs being again used to control bleeding from the gap so formed.

The gauze packs are now withdrawn and replaced by laminectomy retractors

are cut away with it because recurrence may otherwise take place If a neurinoma it may be necessary to sacrifice the nerve root (Fig 30 c) to which it is adherent In doing so the vessel which accompanies the root needs coagulating In removing tumours the greatest care must be taken not to contuse or otherwise damage the cord in any way and heavy coagulating currents *must not* be used *near the cord* All manoeuvres in performing the operation are directed away from the cord; this applies not only to the actual removal of the tumour but to its exposure by laminec tomy In removing the bone considerable force is sometimes necessary and this must at all times be directed outwards and backwards away from the cord

Anteriorly Placed Tumours If the tumour is in front of the cord its removal requires gentle rotation of the cord away from it. This is best done by dividing one or several slips of the dentate ligament and by means of fine dissecting or mosquito type artery forceps attached to the dural extremity of one of the detached slips

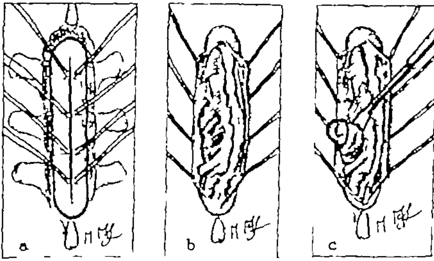


Fig 3 Removal of spinal tumour

The dura has been opened between series of sling sutures
b Tumour exposed lying posterolaterally and crossed by nerve root
Nerve root has been divided and tumour is being dislocated.

rotating the cord outwards and backwards so as to bring the tumour into view (Fig 31) While the cord is thus gently retracted by an assistant the tumour is carefully removed by dissecting it free from its arachnoidal covering

Intramedullary Tumours Fortunately these tumours are rare compared with those which arise outside the cord They are usually of the glioma group such as ependymomata and are dealt with by exposing the tumour through a posterior median incision made into the cord Occasionally gently easing and dissecting with small pledgets of cotton wool frees the tumour so that it can be removed but more often *it is difficult to determine its limits and in these cases Elsberg's procedure* is best adopted The wound is closed and the patient sent back to bed Some ten days later the wound is reopened and it may then be found that the tumour has partly extruded and can then be removed whole or in part with less damage to the cord than would probably ha been the case had primary remo al been attempted

Other Findings A tumour may be closely simulated by certain other space occupying lesions which may cause spinal block and give a positive myelogram. Varicosities of the pial vessels is such a condition and is best treated by decompression alone leaving the dura open over them. Any attempt to thrombose or remove these vessels may be disastrous either as the result of haemorrhage from their abnormally thin walls or from interference with the blood supply of the cord thereby further impairing its conduction. If pain has been a prominent feature of the case it is advisable to divide the nerve root or roots concerned taking care to avoid the varicose vessels in doing so.

Another condition which may resemble tumour is chronic spinal meningitis (meningitis circumscripta serosa of Horsley). An attempt to free the cord from the interlacing strands of arachnoid which are found in this condition should be made.

The closest mimicry of a tumour may be made by a central protrusion of nuclear material from an intervertebral disc (*Fig 21 b*) and in fact such a protrusion is really an anterior extradural tumour. Removal is effected either extradurally or by

Fig 3 Exposure of anteriorly placed spinal cord tumour by rotation of cord by means of a slip of the dentate ligament

an approach through the posterior part of the dural sheath after the cord has been gently retracted in the way already described. Other extradural tumours such as lipomata, neurofibromata and echinococcus cysts may be removed without difficulty the latter after injection of ether or formaldehyde (2 5 per cent solution) into the cysts to kill the scolices.

Dumb-bell Tumours These tumours have intraspinal and extraspinal parts with an intervening isthmus and as a rule are best dealt with in two stages the first in which the cord compression is relieved by removal of the spinal part of the tumour the second when the extraspinal part is excised.

Closure of the Wound

The Dura It is not essential but in most cases desirable to close the dura mater. This is effected with fine silk sutures and any defect which it has been necessary to produce in removing part of the membrane along with a meningioma may be repaired with a piece of pressed-out fibrin foam or gelfoam. If the tumour has

proved to be massive and not removable e g a large intramedullary glioma, the dura is left open for decompression

The Muscles These are approximated with several layers of interrupted catgut sutures this absorbable material being used so as to interfere as little as possible with their subsequent function

Aponeurosis and Skin Fine silk interrupted sutures are used to approximate the edges of the dorsal aponeurosis and interrupted nylon or waxed thread sutures are used for the skin (Fig 32)

A dressing of dry gauze and wool is applied and fixed in position with strapping and except in the cervical region with a many tailed bandage as well

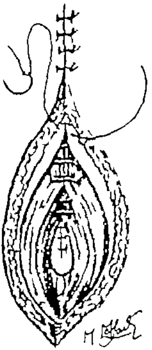


Fig 32 Closure of wound in layers Fine interrupted silk for dura; interrupted catgut for muscles interrupted silk for aponeurosis waxed thread for skin.

AFTER TREATMENT

Deep breathing exercises are instituted as soon as recovery from the anaesthetic is complete The assistance of the physiotherapist is sought early; massage to recovering spastic limbs is to be avoided but the patient is encouraged to try to move the limbs and to move about in bed He should be turned frequently to avoid pressure on bony points The dressing is left undisturbed until the stitches are removed on the tenth day Leakage of cerebrospinal fluid is an occasional complication If such occurs, the intake of fluids should be limited the head kept low and penicillin administered Leakage usually ceases within a few days After the wound has soundly healed he is allowed up If there has been retention of urine care of the bladder will have been an important consideration throughout the course of treatment and until normal micturition has been restored In some cases a supra

pubic cystostomy will have been performed in others repeated catheterisation or overflow incontinence will have developed by the time the patient has come under care Whatever the method of dealing with the urinary retention the greatest care must be taken to minimise infection in the urinary tract Return of conduction in the cord may be considerably delayed by persistent urinary infection

The rate of return of conduction in the cord freed from compression by an intrathecal extramedullary tumour and its degree of recovery of function are in many cases surprising especially with youthful co-operative patients who are in other respects fit and well but even in the aged and in advanced cases an astonishingly complete recovery is by no means rare

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CHAPTER 3

Surgery of the Thyroid Gland

J E PIERCY

THE ANTITHYROID DRUGS AS A PREPARATION FOR SUBTOTAL THYROIDECTOMY

ALL PATIENTS with severe thyrotoxicosis whether the associated goitre is primary diffuse or secondary nodular are prepared for subtotal thyroidectomy by the antithyroid drugs methyl or propyl thiouracil Patients with the moderate degree of thyrotoxicosis which commonly accompanies both the secondary nodular goitre and the single adenoma are prepared by Lugol s iodine alone

The antithyroid drugs act directly upon the thyroid gland by inhibiting the synthesis of thyroxine This results in a lowering of the basal metabolic rate and in an alleviation of the symptoms and signs of thyrotoxicosis The typical hyperplasia and vascularity of the thyrotoxic gland, however remains as before or may even increase

A primary diffuse thyrotoxic goitre is controlled more quickly by the drug than is a thyrotoxic nodular goitre For example a nodular goitre requires approximately three months treatment to reduce a basal metabolic rate of plus 50 to a normal level whereas in a primary diffuse goitre six weeks treatment by the drug would often suffice

An o erdosage of the antithyroid drugs will give rise to myxoedema Operation must not be undertaken on such patients until the basal metabolic rate regains its normal level as myxoedema produces an intolerance to morphine and a thickening of the vocal cords which may result in laryngeal obstruction

The administration of iodine to a thyrotoxic patient produces a rapid improve ment in her condition whilst the gland becomes firmer and less ascular

The benefit gained from the administration of iodine is however only temporary It reaches its maximum at or about the third week, and at such time operation should be undertaken. If iodine has been inad isedly gi en over a long period it must be omitted for at least a month and then recommenced in order to gain its maximum benefit at the time of operation

Subtotal thyroidectomy must never be performed on a patient prepared by one

of the antithyroid drugs alone. These drugs, by increasing the hyperplasia, vascularity and friability, particularly of the diffuse goitre, greatly increase the technical difficulties of the operation. The drug is replaced by Lugol's Iodine for the final three weeks preparation. By this method the goitre is brought to a stage of involution and these difficulties resulting from thiouracil are largely overcome.

The Value of the Antithyroid Drugs

All severely thyrotoxic patients are brought to a comparatively non-toxic state by the use of the antithyroid drugs. Thus the many dangers previously associated with operations upon them have been eliminated.

1. The patient is enabled to undergo subtotal thyroidectomy within a few days of admission to hospital.
2. Post-operative reaction is negligible and thyrotoxic crisis unknown.
3. Children now undergo operation with almost complete safety.
4. The pregnant patient undergoes subtotal thyroidectomy early and with less danger to mother and child.
5. The thyrotoxic patient with a superadded psychosis is brought to a normal metabolic level and there maintained for several months. If this results in an accompanying remission of the psychosis, the operation can be performed without the danger of aggravating her mental state.
6. The diabetic, when brought to a non-toxic state, undergoes operation with less cause for anxiety.
7. The severely thyrotoxic patient with auricular fibrillation and resulting congestive failure is made much safer for operation. (Patients with these cardiac complications are more often found to have only a minimal thyrotoxicosis associated with nodular goitres of long duration. They are not usually prepared with thiouracil.)
8. Preliminary ligation of the thyroid arteries and stage operations are now rarely necessary.
9. The great care and consideration formerly given to the choice of the anaesthetic is now no longer essential.
10. The antithyroid group of drugs is valuable as a diagnostic measure in doubtful cases of thyrotoxicosis. If benefit results from its administration this diagnosis can be made with certainty.

Toxic Manifestations

The antithyroid drugs can give rise to several toxic manifestations. These include pyrexia, headache, rashes, vomiting and diarrhoea, joint pains, swollen lymph nodes, jaundice, leucopenia and agranulocytosis.

Agranulocytosis carries with it a high mortality. It is more likely to develop when a leucopenia is present, but may, however, appear without such warning.

When agranulocytosis is suspected the drug is stopped immediately; when this is proven by a blood count, the patient is admitted to hospital and treatment instituted by means of massive doses of penicillin and blood transfusion.

Contra-indications

Preparation by the antithyroid drugs is contra-indicated when a goitre is actually causing pressure or when it is partially or wholly retrosternal. As the drug may result in an enlargement of the goitre, it may cause or increase pressure symptoms.

PRE-OPERATIVE PROCEDURE

Out-patient Preparation by Methyl Thiouracil

1 The patient's basal metabolic rate is estimated

2 *A leucocyte differential count is made*

3 Two-tenths of a gram of methyl or propyl thiouracil is given once or twice daily

4 The patient is warned to stop taking the drug and to report immediately at *the first symptom of a sore throat or other toxic manifestation*

5 The patient is kept under weekly observation

6 Blood counts are taken periodically and if the white cells are found to have fallen below 4000 per cu mm the drug is temporarily discontinued If it remains *below this level for several days the preparation by the thiouracil drug must be* stopped

In many American clinics the administration of propyl or methyl thiouracil is continued until all evidence of thyrotoxicosis has disappeared. It is our practice to stop the preparation by methyl thiouracil when most of the signs and symptoms of thyrotoxicosis have been eliminated Lugol's iodine minims 5 is then given twice daily for a further two or three weeks, after which the patient is admitted to hospital for subtotal thyroidectomy

During the above out patient preparation the patient is allowed to continue her normal activities unless she is severely toxic or has signs of cardiac decompensation

In-patient Preparative Care

Those thyrotoxic patients who have been prepared as out-patients with methyl thiouracil and Lugol's iodine and admitted to the hospital in a sufficiently non-toxic state undergo operation within forty-eight hours of admission

Those who have been prepared for any reason with Lugol's iodine alone are generally given a longer period of rest in hospital During this time they are carefully assessed When restless and apprehensive they must be handled with the utmost tact and kindness by the medical and nursing staff Phenobarbitone (phenobarbital) is helpful in allaying their anxiety and sleep is ensured by medinal (barbital sodium) at night

A generous diet is ordered and glucose is added to most of the fluids taken Purgatives are contra indicated in thyrotoxicosis as they may start uncontrollable diarrhoea They are replaced by either enemata or glycerine suppositories

No two thyrotoxic patients react alike in their response to rest iodine, and sedatives but a lowering of the pulse rate is the main criterion of improvement Operation may be undertaken with safety when the pulse rate falls to a basic level of approximately 100 per minute

Those thyrotoxic patients who are admitted with auricular fibrillation and signs of congestive heart failure are kept at complete rest in bed Digitalis is given in sufficiently large doses to control the ventricular rate and to eliminate the signs of congestive failure as far as possible Salyrgan or a like preparation is sometimes necessary in addition Quinidine is never given before operation Subtotal thyroidec

tomy is withheld until the physician is satisfied that the signs and symptoms of congestive failure have reached their minimum.

X-rays of the chest are necessary in patients with nodular goitres in order to demonstrate any possible retrosternal prolongation.

A laryngoscopic examination of the vocal cords is made if any change has been noticed in the patient's voice suggesting involvement of a recurrent laryngeal nerve, and always before operating on a regrowth of a gland.

All patients are under careful medical supervision during the period of preparation.

Preparation for Operation

1. *On the day previous to operation*
   Fluid diet is given.
   A small enema or a glycerine suppository, if necessary, is ordered.
   The site for operation is prepared.
   Medinal (barbital sodium) is given at night.
2. *On the morning of operation*
   A further skin preparation is made.
   Omnopon 20 mg. (1/3 grain) and scopolamine 0.4 mg. (1/150 grain) is injected one hour before operation.
   A further injection of half of the above dose of omnopon, i.e. 10 mg. (1/6 grain) and scopolamine 0.2 mg. (1/300 grain), is given half an hour before operation.

Elderly patients with evidence of cardiovascular degeneration, are given only one injection of omnopon and scopolamine.

PRELIMINARIES TO OPERATION

Position of the Neck

An adjustable bridge, which is attached to the operating table, is raised under the patient's shoulders until the neck is extended and prominent. It is undesirable to extend the neck fully as this puts the infrahyoid muscles under tension and makes their retraction difficult during the operation. The bridge can be easily lowered to relax the tension of the neck muscles at any stage of the operation (Fig. 33).

The extended position of the neck can also be obtained by means of a sandbag or cushion placed under the shoulders. This method is, however, less satisfactory, as it entails raising the patient manually for any readjustment of the sandbag.

The Anaesthetic

Anaesthesia is induced by a slow intravenous injection of 0.4 to 0.6 of a gram of pentothal and is continued by means of nitrous oxide with the high percentage of oxygen which is necessary for all thyrotoxic patients.

Endotracheal anaesthesia is reserved especially for those patients with hard and fixed goitres and for those with signs or symptoms of tracheal pressure. These include carcinoma of the thyroid, lymphadenoid and Riedel's thyroiditis, retrosternal goitre, and those goitres with substernal or retroclavicular prolongations.

Exposure of the Neck

The field of operation is exposed during the administration of pentothal. A sterile towel which covers the neck and chest of the patient, is turned upwards and backwards and retained in this position to act as a screen until the injection of the subcutaneous tissues of the neck, as described below is concluded The neck is now extended by raising the shoulder bridge and the skin is swabbed with an antiseptic solution

Subcutaneous Injection of Adrenaline in Saline

The surgeon, or his assistant using a continuous action syringe with a 3 inch needle attached injects the subcutaneous tissues of the neck for an area extending from the thyroid notch above to the suprasternal notch below and laterally as far as the external jugular veins The solution used is 1 200 000 adrenaline in normal

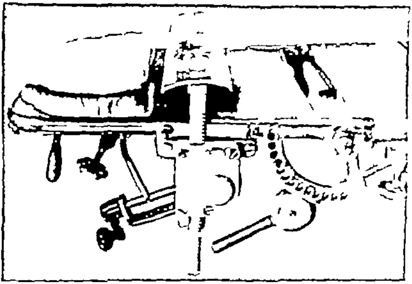


Fig 33 Adjustable shoulder bridge raised for extension of the neck. Hollowed-out head support in position

saline This is made up by adding 0 5 c c of 1 000 solution of adrenaline, from a sterile ampoule, to each 100 c c of normal saline The amount injected is approximately 100 to 150 c c The injection must be given carefully on a plane superficial to the prominent veins Each pressure of the piston is accompanied by a slight withdrawal of the needle to avoid injecting the veins the barrel being refilled as the needle moves forward again The whole area in which the flaps are to be raised is infiltrated in this manner *Although the injection appears to be superficial much* of the solution goes deep to the platysma owing to the extended position of the neck and the prominence of the goitre A few minutes are required for this injection but it ultimately saves time as it lessens the capillary oozing and also facilitates the raising of the flaps by clearly defining the fascial planes I have never seen a patient react unfavourably to this weak solution of adrenaline

A sterile swab soaked in antiseptic solution, is now placed over the neck whilst

the surgeon prepares for the operation Thi interval of a few minutes between the injection and the incision allows for th maximum haemostatic action cf the adrenaline

The Arrangement of Aseptic Towels

Two terile towels are slipped under the nape of the neck from above as the head is held raised One ide of the more uperficial towel is bound firmly over the other in order to cover the chin face and mask A small pad of sterile cotton wool is then tucked into the space on either side of the nape of the neck A large towel

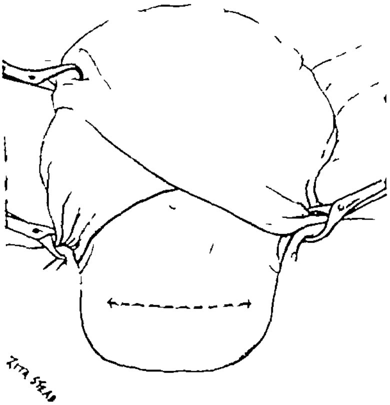


Fig 34 Arrangement of sterile towels.

having a rectangular section cut out above to expose the field of operation covers the body This towel is clipped to the head towel and gi es a perfect exposure of the neck yet completely excludes the face and body (Fig 34)

THYROTOXIC GOITRE (DIFFUSE AND NODULAR)

SUBTOTAL THYROIDECTOMY

The Incision

Its Position and Length The position and length of the incision depend upon the size symmetry and fixity of the goitre It is planned to give the most adequate exposure consistent with the best possible cosmetic result It must be remembered

that with a neck fully extended and already prominent owing to the goitre the incision must be made at a level higher than that planned for the end result otherwise it will be found to lie too low after the operation being then over the manubrium sterni where it will be more noticeable and more likely to become adherent.

The line of incision is slightly convex downwards Its level is approximately 1½ inches above the suprasternal notch and conforms roughly with the line of the clavicles on either side (Fig 36) The incision in the average case extends from one external jugular vein to the other A smaller incision hampers both the adequate raising of the flaps and the further manipulations Furthermore the cosmetic result is little impaired by the longer incision as the lateral extremities of the wound are less noticeable than its centre In a nodular goitre when the main

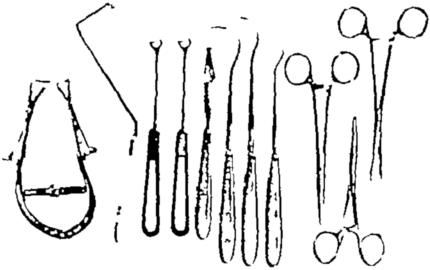


Fig 35 Special instruments used in operations on the thyroid

prominence is large and unilateral the incision on that side is made at a slightly higher level in order to produce a symmetrical scar Three fine scratch marks are made with a needle at right angles to the proposed line of the incision It will be found, when finally closing the skin incision that the lateral guide marks on the lower flap have retracted medially and that they must be approximated to obtain perfect alignment

TECHNIQUE The incision is made with one continuous stroke of the scalpel making certain that the convex edge of the blade is held at a right angle to the skin and that the termination of the incision is on the same level as its commencement There is a natural tendency both to undercut the skin and to terminate the incision at too low a level The incision is continued through the superficial fascia and the thin platysma muscle Care is taken not to go beyond this plane as the anterior jugular veins may be injured The platysma muscle does not extend across

the midline of the neck. *There is a definite line of condensed fascia continuous with* the medial borders of the platysma and bridging this midline space. This fascia which I have called the 'interplatysmal fascia' must be recognized and must be cut carefully in the line of the incision. Reflection of the upper flap is then commenced by touches with the scalpel to the areolar tissue lying between the platysma and the deep fascia laterally and between the interplatysmal fascia and deep fascia centrally. Care is taken to avoid injuring the veins. If injured, they are ligated above and below the puncture and then divided.

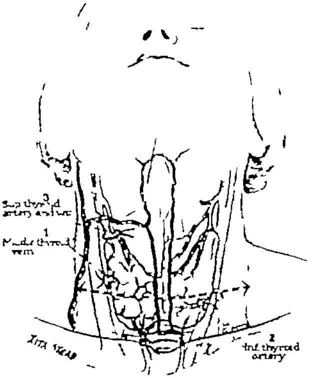


Fig. 36. Showing line of incision in relationship to thyroid gland

This dissection is continued by nicking the areolar tissue deep to the platysma whilst the upper flap is being rolled upwards with the aid of either Gillies' hooks or a piece of gauze (Fig. 37). Using this method the large veins under the deep fascia are not brought forward and are less liable to injury. The upper flap should be raised in the average case to the level of the thyroid notch. In the patient with a very large goitre or one with high upward prolongations the flap is raised to the level of the hyoid bone. *During this reflection* it is necessary to control with forceps several small vessels which may be either ligated with No. OOOO plain catgut or touched with the diathermy.

The lower flap is raised with toothed dissecting forceps and the areolar tissue

deep to the platysma and the interplatysmal fascia, is nicked with the scalpel The central part of the lower flap should be freed in this manner down to the manubrium sterni but the lateral extremities need very little undercutting

Application of Skin Towels

Small sterile towels are applied to the margins of the skin incision The lower skin-flap including the skin towel is grasped centrally by Joll s self retaining retractor which is then partially opened Its upper teeth are then clipped to the subcutaneous tissue of the rolled back upper flap as close to the upper extremity of the dissection as possible (Fig 38 a) This allows wide retraction of the skin without undue tension The towels are now clipped to the lateral extremities of the incision, thereby completely excluding the skin

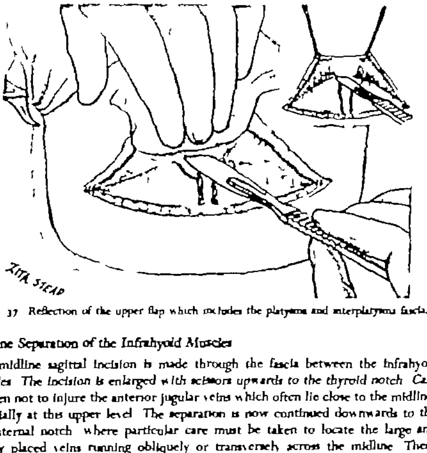


Fig 37 Reflection of the upper flap which includes the platysma and interplatysma fascia.

Midline Separation of the Infrahyoid Muscles

A midline sagittal incision is made through the fascia between the infrahyoid muscles *The incision is enlarged with scissors upwards to the thyroid notch* Care is taken not to injure the anterior jugular veins which often lie close to the midline especially at this upper level The separation is now continued downwards to the suprasternal notch where particular care must be taken to locate the large and deeply placed veins running obliquely or transversely across the midline These are exposed and therefore safeguarded by opening the blades of the scissors between the suprasternal fascial planes and separating them before cutting the fascia

The thyroid isthmus is now visible covered by its deep fascia (surgical capsule) This capsule is opened with blunt dissecting forceps (Fig 38 a) and the forefinger of the left hand is then insinuated between it and the isthmus, down to the front of the trachea With the finger in position the fascia is cut with scissors down the midline in order to expose the trachea and the inferior thyroid veins (Fig 38 b)

Transverse Section of the Infrahyoid Muscles

Preliminary Consideration The decision is made at this stage whether to transect the infrahyoid muscles This depends on the degree of fixity friability and vascularity of the lobe its size the depth of the gland and the tension of the adjacent neck muscles The muscles are cut without *hesitation if the lobe is found to be unduly* adherent friable or vascular or if retraction gives poor exposure The less experienced the operator is in thyroid surgery the more often should he cut the muscles although several outstanding thyroid surgeons including Lahey (1938) section them as a routine Cutting the muscles leads neither to impairment of the cosmetic result nor to any limitation of movements if followed by careful suture It provides a better exposure in a difficult case and facilitates the recognition and ligation of the middle thyroid veins and also the dislocation of the lobe

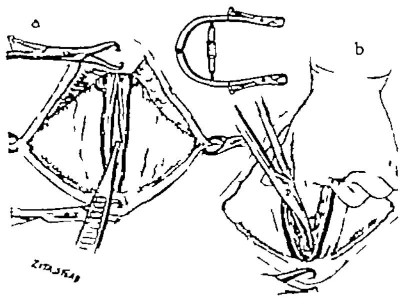


Fig 38

The self-retaining retractor and towel clips in position The infrahyoid muscles have been separated and the surgical capsule is being opened

b The surgical capsule is being inched over the index finger which is palpating the trachea.

TECHNIQUE The infrahyoid muscles are freed from the anterior surface of the lobe and the anterior jugular vein is ligated above and below the proposed line of section. This should be at a high level close to the upper border of the cricoid cartilage The muscles are cut transversely with scissors or scalpel extending as far laterally as the medial border of the sterno-mastoid (Fig 39 c) I see no advantage in applying crushing forceps to the muscles before they are severed

Separation and Retraction of Infrahyoid Muscles

Preliminary Considerations When separating and retracting the infrahyoid muscles it is important to find and follow the plane between the true and the surgical capsules of the thyroid There is a tendency to dissect on a plane superficial to the sterno-thyroid muscle which may be thinned-out and adherent to the lobe Dis

section at this level leads to difficulty in locating the middle thyroid veins and in dislocating the lobe On the other hand if the dissection is made at too deep a level and into the gland substance, troublesome haemorrhage results This bleeding from the surface of the gland is difficult to control with forceps It is preferable to underrun the vessel if large with needle and catgut. Gauze pressure can be applied to smaller vessels or to generalised oozing, whilst continuing the dissection in the correct plane

This potential space between the true and surgical capsules can, with care and adequate retraction be easily found (Fig 39 *b*) The middle thyroid veins can then be isolated and controlled and the lobe rapidly freed and dislocated I consider this to be one of the most important stages in the operation The complete dislocation of the lobe simplifies the recognition and ligation of the inferior thyroid artery and it ensures the safety of the recurrent laryngeal nerve and parathyroid bodies when the lobe is sectioned

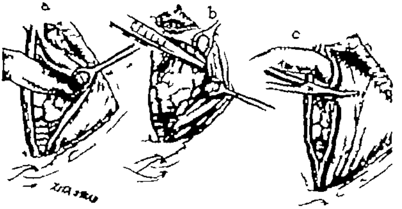


Fig 39

Retraction of both the surgical capsule and infrahyoid muscles.
b Blunt dissection between true and surgical capsules.
Section of the infrahyoid muscles at the level of the cricoid cartilage.

Technique The space between the surgical capsule and the thyroid lobe has been opened in the midline by means of blunt dissecting forceps The assistant slips two small blunt-ended retractors into this space and raises the surgical capsule and infrahyoid muscles upwards and outwards (Fig 39 *a* *b*) At the same time the operator retracts the lobe medially by finger pressure on gauze and sweeps the dissecting forceps between the true and surgical capsules separating the fine mesh of connective tissue between them (Fig 39 *b*) An enlarging space is produced as the dissection and retraction proceed and the middle thyroid veins draining into the internal jugular vein come into view (See Fig 40)

Ligation of Middle Thyroid Veins

These lateral veins vary in size number and position and are occasionally absent. When present they are isolated from the surrounding fascia by blunt dissection the medial and lateral retraction described separates the lobe from the internal jugular vein and puts these isolated veins on the stretch A blunt aneurysm

needle carrying a No. O catgut ligature is passed under the lateral thyroid vein which is tied firmly close to its entry into the internal jugular vein. Forceps or a second ligature is applied to the vein near the gland. The intervening section is then divided close to the gland (Fig. 40). *This leaves a considerable length of vessel* attached to the internal jugular vein which prevents venous haemorrhage from a slipped ligature either at the time of operation or later (J.ll. 1932, p. 557). Occasionally an accessory vein from the lower pole drains into the internal jugular and is dealt with in a similar manner.

Dislocation of Left Lobe

The left lobe, with the exception of its upper pole, is now dislocated freely from its bed by means of the fingers, the assistant meanwhile retracting the infrahyoid

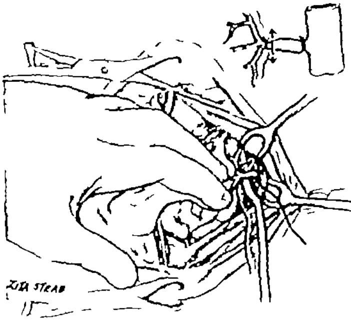


Fig. 40. Exposure, ligation, and section of the middle thyroid vein

muscles and the internal jugular vein laterally. It is often necessary to strip the deep fascia from the postero-lateral border of the lobe either by blunt dissection or by gauze. I often ligate the inferior thyroid artery at this stage if it is large and accessible (see Fig. 43).

Dislocation of the Upper Pole

The upper pole is found to be anchored by the thinned-out sterno-thyroid muscle and deep fascia on its anterior surface and by the deep fascia on its lateral surface and posterior margin. The pole is wedge-shaped (Fig. 41 *b*) with the thin edge of the wedge bound down to the pharynx posteriorly by fascia. With the infrahyoid muscles well retracted this thin muscle layer and the fascia are stripped from the pole. Particular care is taken to strip the fascia from the posterior wedge (Fig.

41 *a*) The forefinger can now be insinuated behind the liberated wedge which has become rounded or cone-shaped (Figs 41 *b c*) and the pole is levered forwards and downwards and dislocated fully into the wound The freeing of this posterior wedge must precede the complete dislocation of the upper pole Occasionally the

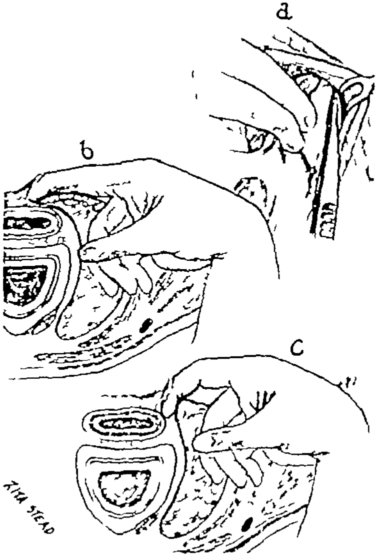


Fig 4

Fascia being stripped to free the posterior wedge of the superior pole

b The index finger is being insinuated behind the wedge of the superior pole after the fascia has been stripped

The wedge [illegible] ced and brought forward and the upper pole is thus mobilised

lobe is tethered by the anterior division of the superior thyroid artery running along its antero-lateral margin This vessel when present, is ligated and severed separately to facilitate the dislocation

Dissecting forceps are now used to open up the potential space between the inner

aspect of the upper pole and the crico-thyroid muscle (Fig. 42 *a*). A Kocher's blunt director is slipped into this space and is passed under the pole to emerge on its outer freed aspect. The upper pole and its vessels now lie superficial to this instrument (Fig. 42 *b*).

Ligation of Superior Thyroid Artery

A large aneurysm needle carrying a strand of No. 1 chromicised catgut is passed laterally along the anterior surface of this director and so under the vessel, whilst

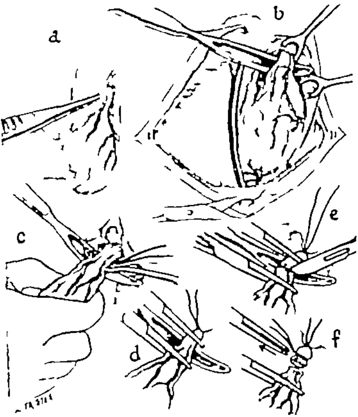


Fig. 42

a. The space between the superior pole and the crico-thyroid muscle is being opened.

b. A Kocher's director has been inserted into this space to lie under the mobilised superior pole and its vessels.

d–f. Ligation and section of the superior thyroid vessels.

the assistant draws the pole downwards and retracts the muscle fibres upwards. The vessels are tied securely where they enter the apex of the pole, the tension on the lobe being relaxed as the ligature is tightened. The ligature is left uncut and two crushing forceps are applied to the vessels between it and the apex of the pole. A scalpel then severs the vessels between the two forceps. A second ligature is applied to the vessels as the upper haemostat is being removed. Both ligatures are cut short after the ligated vessels have retracted behind the muscles. (See Fig. 42 *c, d, e, f*.)

Ligation of the Inferior Thyroid Artery

Preliminary Considerations Ligation of this vessel is an essential step in the operation. With a well-dislocated lobe its recognition and isolation need not be difficult. The artery is not constant in position but it usually passes transversely from under the carotid sheath to enter the postero-inferior surface of the lobe near the junction of its middle and lower thirds. It may, however, emerge at a higher or lower level passing obliquely from above or below. In the great majority of toxic goitres these vessels are large and prominent; they may, however, be small and difficult to locate and are very occasionally absent.

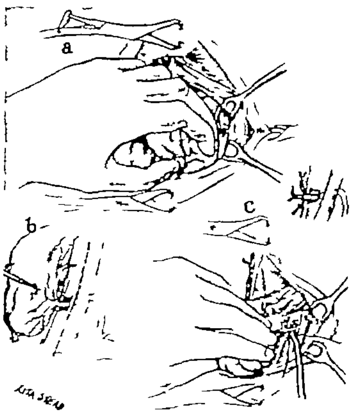


Fig. 43 Ligation in continuity of the inferior thyroid artery

a The deep fascia has been stripped to expose the artery.

b The proximity of the recurrent laryngeal nerve to the artery is shown.

c The artery is ligated in continuity as far as possible from the gland by means of an aneurysm needle.

A study of the cases in this clinic has convinced us that ligation of the inferior thyroid arteries considerably lessens the tendency to regrowth of the gland. It also allows transection of the gland with a minimal loss of blood. It diminishes the danger of post-operative haemorrhage; it enables one to leave more gland tissue behind, and so ensures the safety of the parathyroid bodies and of the recurrent laryngeal nerves.

Ligation of the vessels does not appear to interfere with the function of the

parathyroid bodies for it is not followed by tetany mild and transient symptoms such as tingling of the fingers and toes are only encountered rarely The safety of the recurrent laryngeal nerve is ensured by isolating and ligating the inferior thyroid artery at least half an inch from the nerve

TECHNIQUE (Fig 43) The vessel is recognised or sought for as it approaches the posterior margin of the gland If obvious it is cleared from the surrounding deep fascia with a few strokes of a blunt dissector at a site approximately ¾ inch from the posterior border of the lobe If deeply placed and hidden it is searched for by blunt dissection while the carotid artery is being retracted outward The smaller

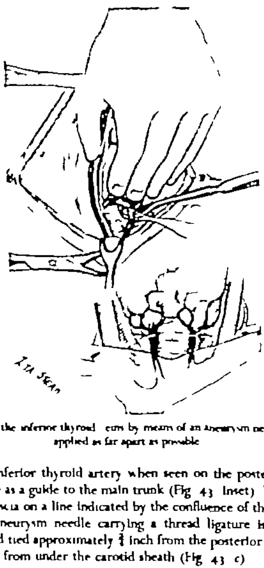


Fig 44. Ligation of the inferior thyroid veins by means of an aneurysm needle. The ligatures are applied as far apart as possible

divisions of the inferior thyroid artery when seen on the posterior surface of the rotated lobe serve as a guide to the main trunk (Fig 43 Inset) This is searched for under the deep fascia on a line indicated by the confluence of the usual three tributaries A small aneurysm needle carrying a thread ligature is passed under the isolated artery and tied approximately ¾ inch from the posterior border of the lobe just as it emerges from under the carotid sheath (Fig 43 c)

Ligation of the Inferior Thyroid Veins

The lower pole is now drawn upwards while the assistant retracts the suprasternal tissues downwards The few rings of the trachea between the lower border

of the isthmus and the suprasternal notch have already been laid bare of deep fascia at an earlier stage The inferior thyroid veins usually two or three in number *passing downwards from the isthmus to the left innominate vein* are isolated from their surrounding fascia by blunt dissection Each vein is now ligated by means of the aneurysm needle The first ligature is placed as far from the gland as possible whilst the second is applied close to the lobe The intervening portion of the vein is then divided close to the ligature nearest the gland (Fig 44) The thyroidea ima artery when present is encountered as it enters the lower margin of the isthmus usually on its right side It is ligated and severed

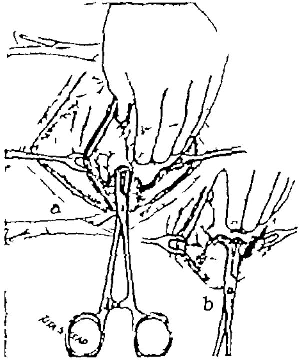


Fig 45

The fascial space between the thyroid isthmus and the trachea is being opened.
b The postero-lateral surface of the lower pole has been clamped and cut.

Section of the Lobes: The Advantages of Controlling and Sectioning One Lobe at a Time

It is the practice of some thyroid surgeons to control and dislocate the right lobe in a manner similar to the left, before resecting the gland (Joll, 1932 [p 564]) Others section the controlled left lobe before dealing with the right one I prefer the latter method for the following reasons

1 It facilitates complete clearance of the isthmus from the trachea whilst the sectioned left lobe is being rotated over to the right side

2 Consequently the pyramidal lobe when present can be followed up and freed with greater ease and certainty

3 It permits of a more effective retraction and a better exposure when dealing with the remaining lobe

Section of the Lower Pole of the Left Lobe

TECHNIQUE A Dunhill's curved forceps is passed up under the isthmus between it and the trachea and its blades are separated to open the fascial space between these structures (Fig 45 *a*) The lower pole is then held forwards and with one blade of the forceps in the fascial space the other is placed along the postero-lateral surface of the elevated pole and the intervening tissue is clamped and cut (Fig 45 *b*) This plane is well away from the recurrent laryngeal nerve

Section of the Upper Pole of the Left Lobe

The freed upper pole is now held forwards Curved forceps are applied to its posterior margin from above downwards and the gland tissue is cut (Fig 46) The inner aspect of the lobe at the level of the upper border of the isthmus is freed

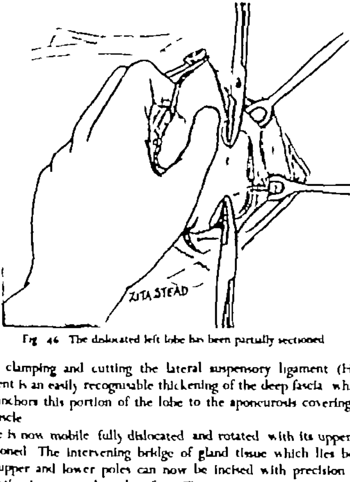


Fig 46 The dislocated left lobe has been partially sectioned

further by clamping and cutting the lateral suspensory ligament (Fig 47 *a*) This ligament is an easily recognisable thickening of the deep fascia which extends from and anchors this portion of the lobe to the aponeurosis covering the crico-thyroid muscle

The lobe is now mobile fully dislocated and rotated with its upper and lower poles sectioned The intervening bridge of gland tissue which lies between the sectioned upper and lower poles can now be incised with precision and safety after inspecting its postero-lateral surface (Fig 46)

The Amount of Tissue to be Conserved

This depends upon (1) the pathology of the goitre (2) its size (3) the degree of toxicity (4) whether the latter has been controlled by thiouracil (5) whether the inferior thyroid vessels have been ligated and (6) the age of the patient

portion of tissue adjacent to the postero-lateral aspect of the trachea (Fig. 47 e). Leaving tissue in this position ensures the safety of the recurrent laryngeal nerve and the parathyroid bodies.

Control of Blood Vessels

Bleeding from the cut surface of the main bulk of the lobe is not severe, but all large veins are controlled by forceps. The remaining fragment of thyroid tissue, in

Fig. 47

The lateral suspensory ligament has been clamped.
b Curved artery forceps applied behind the level of the proposed line of section of the lobe.
The remaining bridge of thyroid tissue is being inched almost to the trachea.
d Section of the lobe is completed by means of scissors.
The left lobe and isthmus are rotated across the midline.

spite of the previous ligation of the superior and inferior arteries, is more vascular. Brisk arterial bleeding, particularly along its tracheal margin, is controlled by forceps or, if deeply placed, by carefully applied haemostatic mattress sutures.

All vessels controlled by forceps on the conserved portion of thyroid tissue are now ligatured with No. O catgut; the superficial and peripheral vessels are ligated first. When the point of a pair of forceps is deeply buried in the tissues, haemostasis is effected by a mattress suture which is tied as the forceps are being removed.

Either additional mattress sutures or a continuous suture is used to control any further oozing from the cut surface

I find it advantageous to suture the mobilised upper extremity of the thyroid remnant to the lower fibres of the crico-thyroid muscle This serves both to anchor it snugly and to control bleeding The remainder of the cut surface is approximated and anchored to the side wall of the trachea by means of interrupted catgut sutures (Fig 47 e)

Mobilisation of the Pyramidal Lobe

Preliminary Considerations A pyramidal lobe is present in over 75 per cent of goitres It arises from the upper border of the isthmus usually to the left of the midline and extends upwards as far as the thyroid cartilage thyro-hyoid membrane

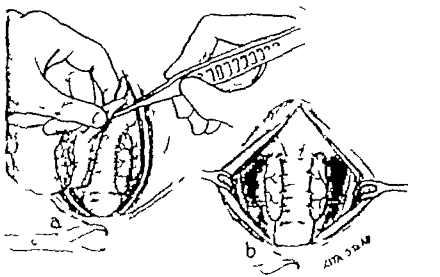


Fig 48

The pyramidal lobe is being freed from the crico-thyroid muscle and from the thyroid cartilage

b Resection of the thyroid gland has been completed. The cut surfaces of the remaining portions are shown approximated and anchored to the trachea.

or hyoid bone It is variable in size and shape being either long and strap-like or short and bulky It is bound down firmly to the crico-thyroid muscle thyroid cartilage and thyro hyoid membrane by an upward prolongation of the deep fascia. Its blood supply is derived from the medial branch of the superior thyroid artery and from a branch of the crico-thyroid artery

It is important to remove the pyramidal lobe completely If a portion is left it can increase in size and give rise to an unsightly swelling, often accompanied by recurrent symptoms of thyrotoxicosis

Technique The upper extremity of the incision separating the infrahyoid muscles is retracted firmly upwards to expose as much as possible of the pyramidal lobe The strong fascia, which binds the pyramidal lobe down to the crico-thyroid muscle and to the thyroid cartilage is stripped from its anterior surface by scissors and

blunt dissection The left lobe and Isthmus are now rotated over to the right exposing the under surface of the base of the pyramidal lobe This under surface extending from base to apex is stripped by blunt dissection from the crico-thyroid muscle and thyroid cartilage (Fig 48 a) Its lateral margins are still tethered by one or two arteries and veins which are now clamped and cut The fascia at its apex is severed thus freeing the pyramidal lobe

In a high prolongation of the lobe adequate exposure is obtained by further separating the infrahyoid muscles upwards *After mobilisation of the pyramidal lobe and isthmus* it is often convenient to cut the lateral suspensory ligament of the right upper lobe

Resection of the Right Lobe

The exposure and resection of the right lobe of the thyroid gland are effected by operating from the left side of the patient

The procedure which has been followed for resection of the left lobe is now repeated on the right side

1 Infrahyoid muscles and deep fascia are separated from the right lobe
2 Middle thyroid veins are ligated and sectioned
3 Right lobe is dislocated
4. Inferior thyroid artery is ligated in continuity
5 Superior pole is freed and sectioned
6 Inferior thyroid veins are ligated and sectioned
7 Right lobe is resected (Fig 48 *b*)
8 Bleeding is controlled

Subtotal resection of the thyroid gland having been completed, the infrahyoid muscles are retracted and the thyroid remnants and remaining cavities are examined Any oozing point is ligated or oversewn

Drainage

Indications It is advisable to drain the residual cavity in the majority of cases This is essential if the resected gland is large and vascular Haematomata often form in cavities which have not been drained Although the clot usually resolves a fluctuating swelling due to serum may appear under the incision about seven days after operation This exudate is liberated by probing the fluctuating point through the skin incision

Method A small vertical incision is made through the fascia covering the infrahyoid muscles at a point on the anterior border of the sterno-mastoid muscle deep to the skin incision The muscle fibres are separated by blunt dissection down to the thyroid space A small strip of corrugated rubber is slipped through this opening into the thyroid cavity to be fixed later by a horsehair suture at the lateral extremity of the skin incision (Fig 49 a) The same procedure may be repeated on the opposite side Direct drainage of both thyroid cavities is ensured by this method

When the infrahyoid muscles have been sectioned sufficient of the lateral extremities of the transected muscles and fascia are left unsutured to allow for the passage of the drainage slip

Suture of the Muscles

The muscles of the neck are relaxed by lowering the shoulder bridge If sandbags have been used to effect the desired extension, they are suitably adjusted

Infrahyoid Muscles If the infrahyoid muscles have been divided they are approximated accurately by means of either a continuous or interrupted No O catgut sutures This is commenced at the outer extremity of the transection and includes the fascia covering the muscles

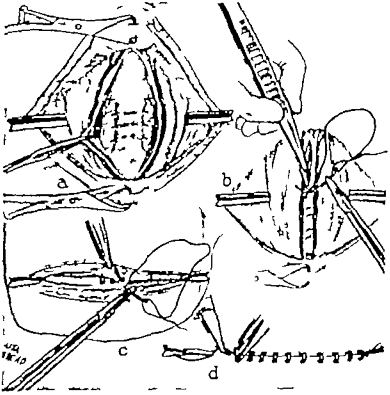


Fig 49

Method of drainage

b Midline suture of the fascia over the infrahyoid muscles.

Suture of the platysma.

d Application of skin lips.

Midline Infrahyoid Fascia The midline separation of the infrahyoid muscles is closed by a continuous No O catgut suture The muscle fibres are not included in the suture but only the overlying fascia is united (Fig 49 *b*) The suturing must be performed carefully in order to avoid pricking the subjacent anterior jugular veins These veins are often difficult to recognise, and may be easily injured I have found the following *milking test* aluable The collapsed veins are milked towards the site of a suspected injury which is then identified by the resultant enous ooze

The test, being repeated after ligation ensures that complete haemostasis has been obtained

The self retaining retractor and skin towels are now removed

Platysma Muscle The platysma together with the interplatysmal fascia is approximated without tension by a continuous suture of No OOOO catgut (Fig 49 c)

Approximation of the Skin

The three skin guide-marks are realigned and secured by the application of clips The remaining skin edges are then accurately approximated in a similar manner (Fig 49 d) and the raised edges are squeezed together firmly with gauze to effect their closest possible contact

Application of Dressings

A mixture of sulphathiazole and penicillin powder is dusted over the wound

Gauze dressings are placed over the incision the more generous amount being applied to its lateral or drainage extremities This protective dressing is held down lightly by two crossed strips of elastoplast each extending from behind the neck to the opposite anterior axillary fold (Fig 50)

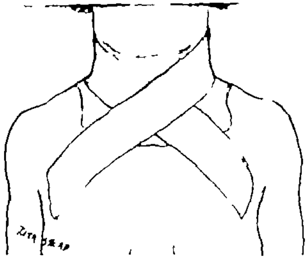


Fig 5 Protective dressing covered by elastoplast

DIFFICULTIES AND ANOMALIES ENCOUNTERED AT OPERATION

1 *Pre-anaesthetic tachycardia* A patient who has been considered ready for operation may whilst under the effect of the pre-operative medication develop a pulse rate of 130 or more Operation is not postponed in this reactive type as the tachycardia will almost certainly settle either during or soon after the administration of pentothal

2 *Thiouracil preparation* of a primary toxic goitre in spite of the administration of iodine makes the operation more difficult The goitre becomes more hyperplastic vascular and adherent, and requires particularly gentle handling It is often necessary to section the infrahyoid muscles to gain a full exposure

3 Avulsion of a friable superior pole from the superior thyroid leash of vessels may result from too forceful traction When this does occur section of the infrahyoid muscles will facilitate their exposure and control

4 *Delivery of a high and adherent superior pole* is not always possible In such an

event, three curved artery forceps are applied as near as possible to its apex The pole is divided between the middle and the distal forceps A haemostatic suture is applied above the proximal forceps and is tightened as it and the middle forceps are removed

5 *An exceptionally short middle thyroid vein* is controlled by only one ligature applied by means of an aneurysm needle The vein is sectioned against the lobe which is then rotated and the distal bleeding is controlled by a mattress suture.

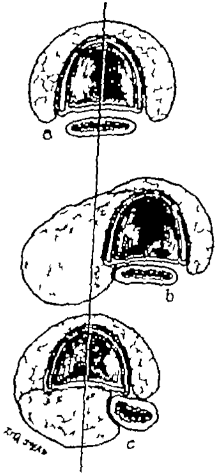


Fig 5 Displacements of the oesophagus and trachea

6 *Bleeding from a torn thyroid vein* quickly obscures the fascial planes This is avoided by the isolation, ligation, and cutting of all veins tethering the goitre before it is dislocated

7 *Injury to a branch of the inferior thyroid artery* can be controlled by digital pressure while the main artery is located and ligatured Forceps must not be applied to the bleeding point for fear of injury to the recurrent laryngeal nerve

8 *A nodule arising from the posterior surface of the lobe may be tethered down by* the inferior thyroid artery In such a rare instance, the artery must be doubly ligatured and sectioned before the nodule can be delivered

9 *Injury to the oesophagus* (Fig 5)

(a) Its lateral displacement together with the trachea may be unrecognised and lead to its injury

(b) A retrotracheal nodule arising from the posterior surface of a lobe may force the oesophagus beyond the midline to the opposite side In this position it forms a bulge resembling a pulsion diverticulum and is liable to injury

10 *Tracheal obstruction may occur*

(a) While the lobe is being dislocated forward and thus producing torsion of a softened trachea The isthmus must be cleared quickly from the trachea to enable it to regain its normal contour or the lobe must be replaced temporarily into the thyroid bed

(b) When a small or softened trachea is associated with laryngeal spasm or is subjected to o erextension of the neck *The shoulder bridge must be lowered and* the operation stopped until the breathing becomes normal

(c) Due to the collapse of a trachea which has been softened by the pressure from a goitre Cyanosis and dyspnoea usually occur just after the lobe has been deli ered This may appear suddenly or gradually and is due to the softened walls of the trachea being drawn together during each inspiration Either intubation or a low tracheotomy is necessary The tracheotomy tube may be removed two or three days later although on one occasion I found it necessary to reinsert the tube for a further few days Tracheal collapse can occur as a late complication

11 *Injury to the trachea* by a scalpel cut must be very rare A small puncture can be closed by a suture reinforced by fascia or muscle A larger injury would necessi tate a temporary tracheotomy Such an accident cannot occur when the isthmus is freed from the trachea by means of scissors

12 *Injury to the recurrent laryngeal nerve* must be considered if sudden stridor or harsh breathing is noticed during any manipulation near the nerve This can occur (a) when ligating the inferior thyroid artery too close to the gland (b) due to forceful avul ion of an adherent lower pole (c) if a haemostatic suture is placed too deeply into the thyroid remnant, or (d) if a haemostat is applied injudiciously to control bleeding Compression of the nerve is relieved by removing the haemostat in its vicinity or by cutting any adjacent ligature The nerve is then exposed and explored

13 *A parathyroid body* if found attached to the excised lobe is removed and implanted into the sterno-mastoid muscle

POST-OPERATIVE CARE

Posture The patient on her return to the ward is placed immediately in the modified Fowler s position

Pain An injection of morphine 10 mg ($\frac{1}{6}$ grain) or heroin 5 mg ($\frac{1}{12}$ grain) is given. Discomfort behind the neck and pain in the region of the gums and ears is frequently complained of these respond to aspirin and phenacetin

Post-operative reaction indicated by a rise of temperature and of pulse rate usually subsides within forty-eight hours a more severe reaction may take several days to settle

All toxic patients are given Lugol s iodine 0 3 c c (5 minims) twice daily for six or seven days Luminal 32 mg ($\frac{1}{2}$ grain) given three times a day is valuable for those patients who are nervous and apprehensive

Vomiting is uncommon and the patient is encouraged to drink as much as possible.

Tracheitis is encountered but rarely. It is relieved by steam inhalations containing tincture of benzoin.

Drainage strips are removed twenty-four hours and skin clips forty-eight hours after operation. Dressings are dispensed with on the second day. The wound is dusted with sulphathiazole powder and is covered by a gauze or lint collar which is attached at the back of the neck by tapes.

Blood-stained serum may collect and give rise to a small fluctuating area. These effusions usually localise at the lateral margins of the wound. They are probed with the blunt end of a needle. Penicillin is ordered if there is evidence of inflammation.

The patient is allowed up on the third or fourth day after operation, depending upon the degree of post-operative reaction. She is usually discharged from hospital on the eighth or ninth day.

Auricular Fibrillation

The administration of digitalis is continued after operation to those patients who were admitted with auricular fibrillation. It is discontinued when the ventricular rhythm has become regular. If this has not occurred by the sixth or seventh day the drug is replaced by quinidine sulphate. A tolerance dose of 0.2 gm. (3 grains) of quinidine is given initially. If this does not cause untoward symptoms, 0.4 gm. (6 grains) of the drug is given every four hours until the ventricular rhythm becomes regular. The return to normal rhythm, when it occurs, usually does so within the first three days of treatment; at such time the dose is reduced to 0.2 gm. every four hours for a further forty-eight hours. In the event of the auricular fibrillation remaining uncontrolled, the drug is discontinued after a six-day trial (Linnell et al. 1946).

Transient auricular fibrillation frequently develops after operation in those patients who had nodular goitres for many years. This temporary irregularity may continue from twelve to twenty-four hours. Quinidine is not indicated in these cases.

POST-OPERATIVE COMPLICATIONS

Haemorrhage

1. *Haemorrhage due to the slipping of a ligature from an artery or from a large vein* will by pressure on the airway quickly produce cyanosis and stridor. Swelling of the neck need not be obvious. The wound must be reopened immediately and the deep clot removed. The acute obstruction having been relieved, the patient may be transported to the operating theatre where the bleeding vessel is located and ligatured under anaesthesia.

2. *Haemorrhage from smaller vessels or from general oozing* gives rise to a slower and more insidious obstruction. Slight cyanosis and huskiness of the voice may be present and a diffuse swelling of the neck is apparent. The patient is transferred to the operating theatre, where the wound is reopened, the clot removed and the vessel, if located, is ligatured.

In either case, if the evidence of obstruction remains after removal of the clot, tracheal collapse is present and tracheotomy must be performed.

Thyrotoxic Crisis

This should no longer be encountered It presents a rapid pulse restlessness a high temperature sweating vomiting and diarrhoea often culminating in delirium Treatment is by morphine oxygen by means of nasal catheters or oxygen tent intravenous sodium iodide (1 gm twice daily) and fluid is given intravenously and by mouth

Pulmonary Complications

Pulmonary complications are unusual pneumonia acute pulmonary oedema and pulmonary embolism being the more frequent

Recurrent Laryngeal Nerve Injury

Recurrent laryngeal nerve injury results in paralysis of a vocal cord

1 If *unilateral* it may give rise to hoarseness or loss of the voice and a stridulant cough on the other hand it may only cause slight huskiness These symptoms will diminish even if the cord is permanently paralysed for in time the normal cord will pass beyond the midline to meet the paralysed one

2 *Bilateral nerve injury* resulting in paralysis of both vocal cords gives rise to intense stridor and dyspnoea on the patient s slightest exertion It often necessitates the institution of a tracheotomy

Evidence of paralysis of one or both vocal cords is apparent either at the time of the injury or soon after the patient has regained consciousness If however the paralysis is due to post-operative oedema of the nerve or to its compression by fibrous tissue days or weeks will elapse before the signs become apparent

Injury to a recurrent laryngeal nerve during subtotal thyroidectomy is in most cases an avoidable accident, whilst injury to both nerves during the operation must be a very rare tragedy Paralysis of both vocal cords is more often the result of an injury to one nerve taking place when operating on a patient who already has an unrecognised paralysis of the other cord It follows therefore that pre-operative laryngoscopy is especially necessary in the patient who has noticed a change in her voice and in those who are to undergo operation for recurrent goitre Should this examination demonstrate a unilateral cord paralysis meticulous care must be taken to avoid injury to the nerve on the normal side

An operation devised by King (1939) to retract and tether the arytenoid cartilages greatly relieves those patients with bilateral vocal cord paralysis

Embolism

Embolism may result from thyrotoxic auricular fibrillation On several occasions (three of them soon after subtotal thyroidectomy) I have seen an embolus lodge in the common femoral artery at the origin of the deep femoral artery In each instance I exposed the artery and the embolus was crushed through its walls by finger pressure and allowed to disperse This procedure resulted in a full recovery in all instances

Myxoedema

Myxoedema may follow (a) subtotal removal of a normal thyroid gland from an apparently thyrotoxic patient, (b) removal of too large an amount of thyroid tissue

from a thyrotoxic patient or (c) when the tissue remaining after operation is functionless

Elderly patients need very little thyroid tissue to maintain their metabolic balance

Patients whose goitres have been further enlarged by thiouracil require more residual thyroid tissue than those prepared by iodine alone

Treatment consists in the administration of thyroid extract The amount given is gradually decreased as improvement occurs Most patients ultimately regain a normal metabolic balance due to the regeneration of their thyroid remnants

Parathyroid Tetany

Parathyroid tetany is usually the result of interference with the blood supply of the parathyroid bodies Symptoms may appear at any time up to forty-eight hours following the operation and may continue for several hours or days

Treatment The mild transient tetany as evidenced by tingling and stiffness of the fingers responds quickly to intensive calcium therapy One to two heaped teaspoonfuls of calcium lactate is given at least four times a day and large quantities of milk are ordered The more severe case is given in addition, 10 c c of a 10 per cent solution of calcium gluconate intravenously Parathyroid extract is reserved for the very rare generalised and acute case Treatment is only necessary for a short time as the function of the parathyroid bodies is soon restored to normal

Tetany resulting from the removal of the parathyroid bodies and which would require prolonged therapy has not occurred in our experience

Unsightly Scars

Unsightly scars are the result of local subcutaneous infection in the majority of cases Treatment of the infection is by penicillin and the sulphonamides The fluctuating area is probed to allow for drainage

A disfiguring scar or adhesions as shown by an upward tugging of the scar on swallowing, may ensue Several months must be allowed to elapse before the scar is excised and the adhesions separated

Keloid formation in a scar is unpredictable the presence of keloid scars elsewhere on the patient however points to this possibility Two or three short treatments by x ray therapy improve the condition Excision of a keloid scar is rarely indicated

RESULTS OF SUBTOTAL THYROIDECTOMY

The following figures are based on the last 1000 operations performed at this clinic Difficult cases including recurrences are referred from many parts of England and Wales and all patients irrespective of age initial cardiac decompensation or degree of toxicity undergo operation

Operability rate thus attains the high figure of 99 8 per cent

The known recurrence rate is 0 5 per cent In the eight years before the commencement of this series during which time the technique did not always include ligation of the inferior thyroid arteries this rate was 4 3 per cent

Classical myxoedema occurred in 0.4 per cent of patients Approximately a further

n patient or 1 per cent developed hypothyroidism as shown by an excessive crease of weight and an intolerance to cold weather The administration of yroid extract ha been found necessary only until uch time as the metabolic lance has been restored to normal by regeneration of the thyroid tissue

Tetany occurred in 0 2 per cent of cases but a further 1 2 per cent manifested ansient symptoms The latter responded to intensive calcium therapy which was nly required for a few day

Vocal cord paralysis with permanent symptoms was recorded in 0 4 per cent and ith transient symptoms in 1 1 per cent of cases

Operati e mortality was 0 6 per cent Three of these patients had suffered from uricular fibrillation and congestive heart failure on admission to hospital

AUSE OF DEATH	TIME AFTER OPERATION	AGE
ardiac failure	5 hours	64
uricular fibrillation ost-operativ haemorrhage	hours	53
ulmonary embolism	6 days	51
uricular fibrillation Cardiac failure	9 days	74
Cardiac fa lure	12 day	55
Auricula fibrillation Pulmonary embol sm	12 day	7

Partial thyroidectomy produces symptomatic relief in more than 90 per cent of thyrotoxic patients whilst a large measure of health can be restored to those with erious complications such as auricular fibrillation Seventy-eight per cent of these ea e the hospital after operation with a normal cardiac rhythm. This is also borne out by Keynes (1935)

It is generally recognised that the nursing profession is an exceptionally arduous and exacting one The fact that of the seventy nurses who underwent partial thyroidectomy all returned to full duty is an indication of the efficacy of the operation

ADENOMA OF THE THYROID

All discrete adenomata, toxic or non-toxic, should be removed for the following reasons

Malignancy occurs in over 10 per cent of non toxic adenomata.

Toxicity occurs in the majority These often give rise ultimately to auricular fibrillation and congestive heart failure

The continued growth of an adenoma by displacing the trachea and larynx, will eventually cause pressure symptoms

An irritating cough or dysphagia is frequently caused by a small adenoma arising from an upper pole and exerting pressure on the larynx or pharynx respectively

Haemorrhage may occur into the substance of an adenoma giving rise to sudden pain and pressure

REMOVAL OF A DISCRETE ADENOMA

The same steps and technique are followed as those used to expose a thyrotoxic goitre The incision must be sufficiently long to allow for exploration of both lobes

The gland is usually approached through the interval between the sterno-hyoid muscles When a large adenoma has produced gross displacement of the trachea it may be approached by splitting the fibres of the thinned-out infrahyoid muscles which lie over it

The middle thyroid vein is frequently absent or displaced when the lobe has been replaced by an adenoma This allows for easy and confident forward dislocation of the lobe containing the adenoma The inferior thyroid artery is isolated and ligated in continuity It is easily found having been elongated and displaced forwards by the growth of the adenoma Particular care must be taken in safeguarding the recurrent laryngeal nerve It often lies in intimate contact with the attenuated thyroid tissue covering the postero-internal surface of the adenoma

The further procedure depends upon the size and toxicity of the adenoma

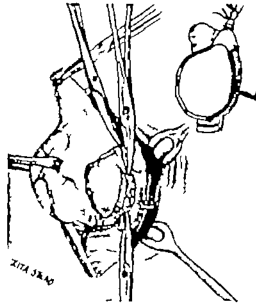


Fig 5 Removal of large toxic adenoma.

Large and Toxic Adenoma

The superior thyroid artery is ligated and the upper pole and isthmus are removed in addition to the adenoma

The liberated upper pole and the adenoma are held well forwards A haemostat is applied from above downwards to the posterior margin of the upper lobe This thin layer of thyroid tissue is cut which exposes the posterior aspect of the adenoma at its upper limit A further haemostat is applied to the base of the adenoma below and the tissue is cut (Fig 52) One blade of a pair of curved scissors is now passed into the space under the adenoma and the thin bridge of compressed tissue which still envelops its postero-lateral aspect is cut The adenoma has now been partially enucleated from its bed and i rotated with the superior pole towards the midline whilst the narrow bridge of thyroid tissue between it and the trachea is cut from

below upwards with scissors. The adenoma, superior pole and isthmus are now rotated across the midline and are removed (Fig. 53). The thin margins of preserved thyroid tissue are brought together and the bleeding is controlled by a continuous catgut suture.

Small and Non-toxic Adenoma

The superior pole is left intact. The thyroid tissue both above and below the adenoma is grasped with haemostats and cut. *The adenoma is then partially excised* with a surrounding zone of normal thyroid tissue and is then brought forwards. The thyroid tissue between the trachea and the adenoma is clamped and incised. The adenoma and isthmus are now rotated across the midline and are removed. The cavity in the lobe is closed with a continuous catgut suture (Figs. 54, 55 and 56).

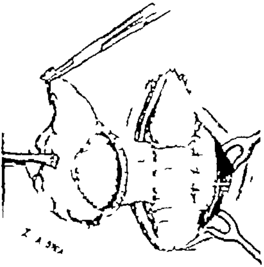


Fig. 53. Removal of large toxic adenoma.

Drainage is instituted when a large residual space remains after the removal of an adenoma.

In all operations for adenomata the lobe of the opposite side must be explored (Piercy, 1945). If an adenoma is discovered it is enucleated or if the lobe is hyperplastic its anterior surface is resected.

Cysts of the Thyroid

Cysts of the thyroid are thin walled and may be easily ruptured during their enucleation. It is preferable to resect them with a surrounding *margin of thyroid* tissue. If the whole lobe has been expanded by the cyst it should be removed.

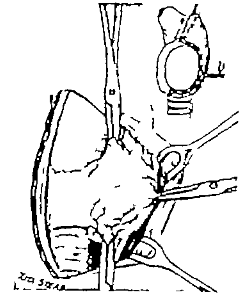


Fig 54. Excision of small non-toxic adenoma.

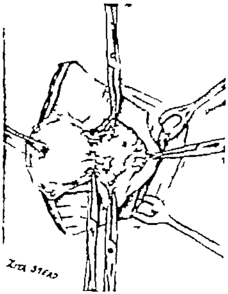


Fig 55 Removal of small non toxic adenoma with surrounding zone of normal thyroid tissue

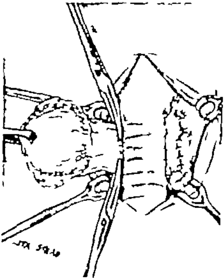


Fig 56 Removal of small non-toxic adenoma

RECURRENT GOITRE

Regrowth of either a diffuse or a nodular goitre may occur after subtotal thyroidectomy The apparent recurrence following the removal of a discrete adenoma is not a regrowth It is the result of the continued growth of an adenoma which was small and unrecognised at the initial operation.

A recurrence is usually due to the removal of an inadequate amount of thyroid

tissue or to the fact that the inferior thyroid artery has not been ligated The recurrence rate in such unligated cases may be from 2 to 6 per cent whereas it is only a fraction of 1 per cent when the arteries have been tied

The incomplete removal of a pyramidal lobe is often followed by hypertrophy of the remaining portion This will ultimately produce an unsightly swelling in the midline of the neck which is often accompanied by a recurrence of toxic symptoms

REMOVAL OF A RECURRENT GOITRE

This may provide one of the most difficult operations in thyroid surgery and may tax the skill of even the experienced thyroid surgeon to the utmost The adhesions resulting from the first operation make it difficult or impossible to find a line of cleavage between the gland and the deep fascia The internal jugular vein is often adherent to the gland whilst the recurrent laryngeal nerve and parathyroid bodies are difficult to locate being either hidden by fibrous tissue or adherent to the lobe

Technique

The operation scar is excised or if necessary a higher incision is made The upper and lower skin flaps are reflected As the regrowth is usually deeply placed and well away from the midline it is approached by splitting the fibres of the sterno-hyoid muscle just anterior to the sterno-mastoid muscle This enables the lobe to be reached without the necessity of burrowing under the pretracheal muscles and separating the adhesions binding them to the lobe The adhesions are less dense on the lateral aspect of the regrowth and once the line of cleavage has been found a retractor is slipped into the space Curved scissors are now used to separate the adherent pretracheal muscles from the antero-lateral aspect of the lobe The exposed lobe is then grasped with gland forceps and is raised and slightly rotated towards the midline Further dissection is proceeded with by means of scissors and, when possibl with non-toothed dissecting forceps The internal jugular vein is freed from the lobe and is retracted After this step it is usually easy to strip the fascia from its postero-lateral aspect The lobe is then dislocated forwards and the inferior thyroid artery is ligated in continuity

The position of the recurrent laryngeal nerve and a parathyroid body is sought for before the lobe is excised Particular care must be taken to avoid injuring the trachea when separating the adherent medial aspect of the lobe from it.

RETROSTERNAL GOITRE

The commonest examples of intrathoracic goitre are the substernal prolongation of a nodular goitre or a discrete adenoma which has arisen from the lower pole of a thyroid lobe The retrosternal mass may ultimately reach enormous dimensions, but is often present for many years without gi ing rise to any noticeable signs or symptoms of pressure A goitre may not be discernible in the neck and auricular fibrillation can be the first symptom leading to its discovery by x ray examination of the chest The upper limit of the tumour lying deeply under the clavicle may be palpable only when the patient swallows

Early symptoms of pressure consist in a sensation of fullness in the neck slight

stridor on exertion and huskiness of the voice The trachea is usually displaced laterally and may be palpable lying under the sterno-mastoid muscle

More severe symptoms of pressure gradually develop as the goitre increases in size. Stridulant breathing is apparent even at rest the cough becomes harsh and brassy and the voice hoarse and indistinct Cyanosis of the face is noticeable, particularly after exertion

Sudden pressure may occur the result of haemorrhage into either a known or hitherto unsuspected retrosternal goitre Pain is a constant feature accompanying this complication

The x ray picture of a retrosternal goitre may give an erroneous idea of its size and depth and can leave the impression that its removal would be a formidable

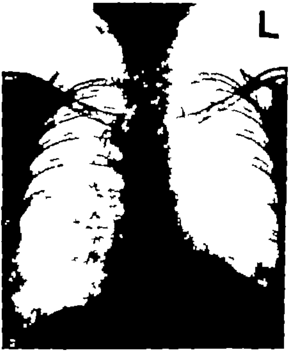


Fig 57 A large retrosternal goitre.

undertaking (Fig 57) In point of fact the reverse is often the case for it is rarely necessary to split the sternum to deli r even the largest retrosternal goitre

The true intrathoracic or aberrant goitre which originates in the mediastinum, is rare It can only be removed after first splitting the sternum for it is often both deeply placed and adherent having its blood supply derived from essels arising in the mediastinum Radio-acti e iodine and the Geiger Muller counter are valuable aids in locating these aberrant goitres

OPERATION FOR RETROSTERNAL GOITRE

The anaesthetic is gi en by the endotracheal method

The same technique is followed in exposing the lateral lobes, as that described for thyrotoxic goitre Particular care is taken to avoid injury to the superficial and the anterior jugular eins which are often enormously dilated

Freeing the Lateral Lobe

1 The infrahyoid muscles are sectioned over the lobe to which the retrosternal mass is attached

2 The middle thyroid veins are ligated and severed

3 The superior pole is liberated after ligation of its vessels

4 The inferior thyroid artery is ligated in continuity

5 The inferior thyroid veins are ligated and sectioned This is a most important step in the operation These veins which drain into the left innominate vein often with a displaced lateral thyroid vein are found stretched over the superior aspect of the retrosternal adenoma and so bind it down in the mediastinum The fact that they are stretched and under tension may make their recognition difficult Each vein must be carefully isolated doubly ligated and severed at the point where it disappears under the clavicle before a safe delivery of the tumour can be undertaken (Figs 58 and 60) It is unusual to find any further vascular connections

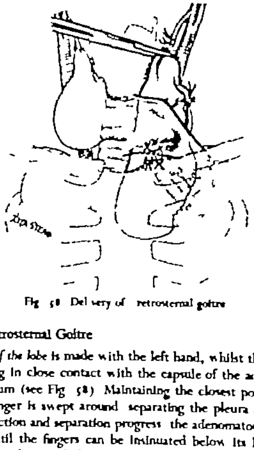


Fig 58 Delivery of retrosternal goitre

Delivery of the Retrosternal Goitre

Upward traction of the lobe is made with the left hand, whilst the forefinger of the right hand keeping in close contact with the capsule of the adenoma, is inserted into the mediastinum (see Fig 58) Maintaining the closest possible contact with the capsule the finger is swept around separating the pleura and cellular tissues from it As the traction and separation progress the adenomatous mass is gradually drawn upwards until the fingers can be insinuated below its lower margin The tumour is then levered upwards from the mediastinum and delivered into the neck

Intracapsular Evacuation

The intrathoracic goitre after being partially freed by the above method may be found to be too large to pass through the upper thoracic aperture It is then

drawn upwards as far as possible above the clavicle and held in that position. The capsule is incised on its anterior surface and an index finger is passed through the opening to break down and evacuate some of its soft semi-cystic contents (Fig 59) In this manner the adenoma is diminished in size This enables it to be drawn still further out of the mediastinum as the index finger frees its capsule from the deeper mediastinal tissues The pressure applied to the capsule forces out still more adenomatous material until finally the retrosternal goitre can be manipulated through the upper thoracic aperture and delivered into the neck

The freed lobe and the adenoma are resected The final stages of the operation are similar to those used for a cervical goitre The resulting cavity is drained

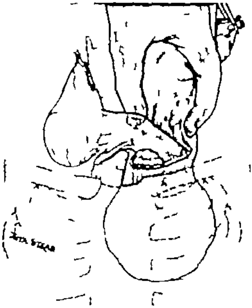


Fig 59 Intracapsular evacuation to enable delivery of a large retrosternal goitre

Splitting the Sternum

This may be necessary to enable delivery of an impacted retrosternal goitre when it is of a solid consistency or when its capsule is adherent to the mediastinal tissues It is essential when the retrosternal tumour is found to be malignant and when dealing with a true or aberrant intrathoracic goitre

A midsternal incision which supplements the usual transverse cervical incision (Dunhill 1922–1923) is made down to the level of the second or third intercostal space (Fig 60) The lateral margins of the sternum between the second intercostal spaces are cleared of muscle and periosteum the periosteal elevator is then insinuated under the sternum on either side A finger is passed under the sternum from the suprasternal notch to separate any adhesions between the adenoma and the bone The sternum is then cut transversely with bone-cutting forceps between the second intercostal spaces It is sectioned down its midline from the suprasternal notch to the transverse section by means of a Sauerbruch's sternal splitter The

cut margins of the sternum are held apart by a self retaining retractor which will give ample space for the removal of the tumour The cut edges of the sternum are finally held together by interrupted catgut sutures applied to the periosteum on its anterior surface The space left by the removal of the tumour soon fills assisted by the expansion of the lungs Drainage is effected through the cervical incision only

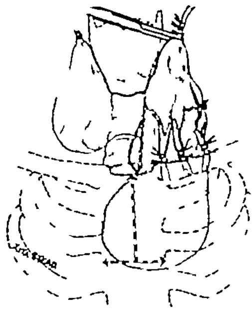


Fig 60 The line of incision through the sternum to allow for its separation in order to deliver an impacted retrosternal goitre

CHRONIC THYROIDITIS

Chronic thyroiditis is represented by lymphadenoid goitre and Riedel s thyroiditis It is unlikely that these two types of goitre are due to the same cause or that one is a later stage of development of the other Many causes have been suggested but none of them has been proven

Operation is not indicated in either condition unless the goitre is giving rise to pressure on the airway or on the oesophagus As however the early lymphadenoid condition may resemble a toxic nodular goitre and as a Riedel s thyroiditis may closely simulate a carcinoma of the thyroid, operation is often performed on them because of mistaken diagnosis

LYMPHADENOID GOITRE

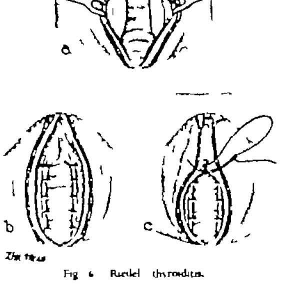
In its early stages this may closely simulate a bilateral nodular toxic goitre The lymphadenoid condition must be considered when the nodules on palpation are found to be discrete and unusually smooth and firm As the condition progresses the entire gland becomes involved in the lymphoid infiltration Its lobules become very hard smooth and discrete and signs of hypothyroidism develop

Pressure symptoms when they occur are mild and consist of a sense of constriction in the neck dyspnoea and hoarseness of the voice

Treatment

Treatment becomes necessary when pressure symptoms occur Subtotal thyroidectomy is performed The inferior thyroid arteries are not ligated. Only sufficient gland is left to protect the recurrent laryngeal nerves and the parathyroid bodies To leave more is to invite a regrowth of the non-functioning tissue The goitre is easily delivered from the surrounding muscles and fascia since the lymphadenoid infiltration does not spread beyond its capsule There is very little bleeding, during either the separation or the resection of the gland. The external surface of the projecting nodules has a new potato-like appearance whilst their cut surfaces suggest the colour of old ivory

Dried extract of thyroid gland must be administered in perpetuum in order to control the associated hypothyroidism



Zin tras

Fig 6 Riedel thyroiditis

F rsion of isthmus
b Suture of pretracheal muscles to sides of trachea
Suture of ov rlying fascia

RIEDEL'S THYROIDITIS

The main characteristic of this condition is fibrosis which not only in ol es the gland but spread beyond its capsule t the surrounding fascia and muscles The gland becomes ery hard and fixed though not greatly enlarged The fibrosis is occasionally confined to only one lobe or to a part of a lobe Its later stages are associated with hypofunction of the gland

Riedel s thyroiditis although closely simulating carcinoma of the thyroid as regards its firmness and fixation is unl ke noma in that the gland retains its

anatomical outline which allows for the recognition of its lobes, superior poles and isthmus.

Operation

Operation is indicated when there is evidence of pressure.

1. *When only one lobe is involved.* The major portion of the lobe and the isthmus are removed to relieve the unilateral pressure. The periglandular adhesions make it extremely difficult to dissect the pretracheal muscles from the lobe.

2. *When the whole gland is involved.* The isthmus of the thyroid gland is excised in order to relieve the constriction of the trachea (Fig. 61, *a*). It is unnecessary to interfere with the lateral lobes. The inner borders of the infrahyoid muscles are retracted laterally and are sutured to the sides of the trachea in order to isolate one cut lobe from the other (Fig. 61, *b*). This prevents scar tissue forming between them across the midline which would eventually result in a further constriction of the trachea. The fascia overlying the infrahyoid muscles is freed from them and then united in the midline (Fig. 61, *c*). This latter procedure is an addition to that described by Lahey (1944).

ACUTE THYROIDITIS

Acute suppurative thyroiditis is uncommon. Its onset is sudden and gives rise to severe pain in the neck, pain on swallowing, hoarseness of the voice and pyrexia. There is a generalised swelling of the thyroid gland which is tender on palpation. Suitable chemotherapy and penicillin are administered. It is not uncommon for an abscess to localise in one lobe. When this occurs and deep fluctuation is elicited the abscess is drained by a suitably placed incision.

Acute non-suppurative thyroiditis differs from the above by a more insidious onset, a milder course and resolution without suppuration. Occasionally the signs of inflammation will follow a haemorrhage into either a nodular goitre or an adenoma. The tender swelling is then confined to one lobe and gives rise to pressure symptoms. The inflammation and swelling usually resolve spontaneously but it may be necessary to aspirate the encysted fluid. In either event the adenoma should be removed some months later.

CARCINOMA OF THE THYROID

The incidence of carcinoma of the thyroid varies in different clinics throughout the world from 1 to 4 per cent. Almost all occur in the adenomatous type of goitre—more than 10 per cent of the single non-toxic adenomata and about 3 per cent of the nodular goitres becoming malignant.

Carcinoma of the thyroid may be conveniently classified in the following groups: (1) obvious, (2) suspect, and (3) hidden.

CLINICALLY OBVIOUS CARCINOMA

This is shown by fixation, granite-hard nodularity and loss of outline of the lobes. At this stage the malignancy is advanced and the growth has already broken through the true capsule of the gland and has infiltrated the surrounding structures.

The role of surgery is to remove as much of the malignant tissue as possible. This is an essential preliminary in order to obtain the full benefit of subsequent deep x-ray therapy, and to allow for the institution of a tracheotomy when necessary.

Procedure

The carcinoma may be present in one or both lobes or may be encountered in a very late stage

1 *When one lobe is in ol ed* it entails removal of the lobe and *isthmus any palpable* regional nodes and the strap muscles of the same side It may be necessary to sacrifice the recurrent laryngeal nerve on that side Deep x ray therapy is instituted as soon as the wound has healed

2 *When both lobes are invol ed* each side is dealt with similarly but sufficient thyroid tissue is retained in order to *protect the recurrent laryngeal nerves It is* a wise precaution to institute a temporary tracheotomy as subsequent x ray therapy may cause oedema of the tracheal mucous membrane

3 *In the very late stage* associated with signs and symptoms of pressure operation is still justified The trachea is carefully cleared of growth and a tracheotomy is *performed, to be followed by deep x ray therapy*

It may be possible to deliver retrocla icular or retrosternal extensions unless these are found to be adherent.

CLINICALLY SUSPECT CARCINOMA

Malignancy is suggested when a known nodular goitre or discrete adenoma, which has been stationary for many years suddenly begins to increase in size

Procedure

The gland is exposed and the diagnosis is verified A haemorrhage into an adenoma must be excluded

As the carcinoma has spread beyond the capsule of the adenoma and has invaded the surrounding thyroid tissue, the lymphatics and possibly the veins are involved by growth This necessitates a block dissection on that side of the neck (Joll, 1932) It entails removal in one mass of that lobe isthmus and the anterior part of the opposite lobe together with regional lymph nodes internal jugular vein sterno-mastoid and strap muscles This is followed by deep x ray therapy

CLINICALLY HIDDEN CARCINOMA

Carcinoma particularly in the case of non-toxic adenomata, is often first diagnosed either at the time of operation or after routine microscopy As the incidence of malignancy is so high *in the discrete adenoma, it follows that*

1 All discrete adenomata should be removed.

2 Careful examination is required at the time of operation for evidence of malignancy

3 All adenomata should be completely excised with a wide surrounding zone of *normal thyroid tissue as the diagnosis of malignancy may* only be made later on microscopic examination

Procedure

1 When malignancy is diagnosed at operation.

(a) *When the growth is confined ithin the capsule of the adenoma* The lobe containing the adenoma the isthmus and the anterior part of the opposite lobe are removed

(b) *When the capsule of the adenoma has been invaded:* This entails removal of the involved lobe, isthmus and anterior portion of the opposite lobe The operation is followed by deep x ray therapy

(c) *When the carcinoma has spread beyond the capsule:* As the surrounding thyroid tissue is involved a block dissection on that side of the neck is essential followed by deep x ray therapy

2 **When unsuspected malignancy is diagnosed initially by microscopy**

(a) If the growth is found to be confined within the capsule of the abdomen further operation need not be undertaken

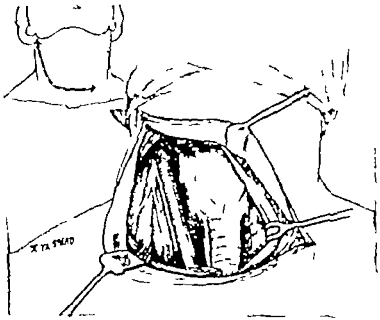


Fig 61 Block dissection of one side of the neck for carcinoma of thyroid lobe

(b) If the capsule and its surrounding thyroid tissue are found to have been invaded—it is justifiable in selected cases to reoperate and to perform a block dissection. This is followed by deep x ray therapy

(c) If the blood vessels of the surrounding thyroid tissue are found to have been invaded—the condition has become widespread and is beyond the aid of either radical surgery or deep x ray

UNILATERAL BLOCK DISSECTION OF THE NECK

1 The cervical incision is extended upwards on that side demanding the block dissection.

2 The sterno-mastoid and infrahyoid muscles are divided close to the sternum and clavicle.

3 The internal jugular vein is exposed on turning these muscles upwards It is sectioned between ligatures which have been applied as low as possible

4. The inferior thyroid artery and veins are ligatured and cut
5. The anterior part of the adjacent lobe is sectioned and is rotated across the midline whilst the isthmus is freed from the trachea
6. The affected lobe is freed from the side of the trachea
7. The superior thyroid vessels are ligated and severed
8. The internal jugular vein is freed ligatured and sectioned at a high level.
9. The prethyroid and sterno-mastoid muscles are divided as high as possible
10. The operation is completed by removing en bloc the affected lobe, the sectioned muscles and internal jugular vein the lymphatics, fascia and regional lymph nodes (Fig 62)

LATERAL ABERRANT THYROIDS

These ectopic foci of thyroid tissue represent metastases into lymph nodes from a small impalpable carcinoma of the adjoining thyroid lobe.

Treatment consists in the removal of all palpable nodes and the corresponding lobe and isthmus of the thyroid This is completed by a course of deep x ray therapy

RADIO-ACTIVE IODINE

1 Carcinoma of the Thyroid

(a) In occasional cases of thyroid carcinoma the neoplasm and any metastases take up iodine strongly and can be treated effectively with radio-iodine Such patients have been restored to health and so maintained by repeated doses of the drug It is not yet clear whether a final cure can be obtained

(b) In a second and larger group of cases the radio-iodine uptake by the neoplasm is too weak to offer any hope of improvement by such treatment In this group however after subtotal thyroidectomy and possibly the use of the thyroid-stimulating hormone or thiouracil sufficient uptake may be induced to allow of effective radio-iodine therapy Radio-iodine can also be valuable in these cases as a preliminary to thyroidectomy Given as a tracer dose the comparative uptake of the two lobes and therefore their comparati e involvement by the growth is indicated by means of the Geiger Muller counter With this information the surgeon can then proceed to remove the thyroid, retaining the posterior margin of the less involved lobe in order to protect at least one recurrent laryngeal nerve

(c) In a third group comprising the majority of thyroid carcinomata, no radio-iodine uptake can be demonstrated and the case is unsuitable for such treatment.

The degree of radio-iodine uptake in these groups corresponds roughly with the histological differentiation of the neoplasm Since, however exceptions to this rule occur every case of thyroid carcinoma with metastases should be studied with radio-iodine

2 Hyperthyroidism

This condition has on occasion been effectively treated by radio-iodine It carries only a low risk of myxoedema or other immediate complications par ticularly if the size of the thyroid and its radio-iodine uptake and discharge are correctly estimated No late induction of neoplasm has been reported

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CHAPTER 4

Parkinson's Disease

Radical Division of the Lateral Pyramidal Tract for Tremor

LESLIE C OLIVER

Many drugs have been tried for the relief of the distressing symptoms of Parkinsonism. None of them however has given impressive results The first surgical attack on the syndrome appears to have been made by Pollock and Davis (1930) who divided sensory roots in an attempt to eliminate tremor but they found that although there was relief from rigidity the tremor was not affected In the same year Puusepp tried the effect of dividing the posterior columns of the spinal cord but reduction of rigidity was the only beneficial result to set against the evident disadvantage of this chordotomy In 1932 Foerster and Gagel found that section of the antero-lateral region of the spinal cord had no effect on the tremor or the rigidity

Putnam made a courageous and determined attack on the disease in 1933 and published his result in 1940 It was known that if a patient suffering from Parkinson s disease became also the victim of a cerebral apoplexy the tremor was abolished on the side of the paralysis This fact combined with Rothmann observation (1903) that section of the lateral pyramidal tracts in monkeys produced little disability led Putnam to perform division of the lateral pyramidal tract for unilateral cases of Parkinson tremor He reported 7 cases in which the results appeared to be worthwhile A cut in the cord was made to a depth of 4 mm. as shown in Fig 63

Bucy and Case (1939) succeeded in abolishing tremor by ablation of the motor and premotor cortex but at the cost of cortical paralysis Klemme (1945 1948) working in St Louis claims that excision of the premotor cortex immediately in *front of the electrically responsive motor area gives* excellent results both in regard to relief from tremor and restoration of function. He has performed a large number

of operations but a detailed analysis of his results is awaited. He bases the rationale of his operation on the contention that there is a balanced functional relationship between the premotor cortex and the basal ganglia transmitted by a premotor cortico-spinal bundle to the common path cell. He believes that in Parkinsonism this balance is disturbed by involvement of the basal ganglia and that it is restored by excision of the premotor area. Klemme limits his operation to patients under 50 years.

The effect of total thyroidectomy on the disease was reported by Myerson and Berlin (1934), but the operation has not established a place in the treatment of Parkinson's disease.

Dodd has performed cervical sympathectomy for Parkinsonism and was kind enough to refer some of these cases to the author after operation as he considered that they had not been improved.

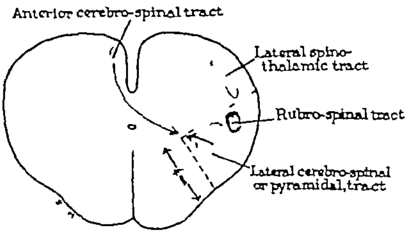

Fig. 63. Cross-section of the spinal cord showing the extent of the Putnam chordotomy and some of the tracts involved.

Myers, quoted by Putnam (1940), claimed that tremor could be relieved by ablation of the head of the caudate nucleus approaching it through the frontal lobe. This would appear to be a formidable operation for the average case of Parkinson's disease.

RADICAL DIVISION OF THE LATERAL PYRAMIDAL TRACT

This account is based on work carried out at the Neurosurgical Centre at Oldchurch Hospital, Romford, the Royal Northern Hospital, and the West End Hospital for Nervous Diseases. The operation performed was a development of the chordotomy introduced by Tracy Putnam and described above.

It cannot be stressed too strongly that chordotomy is not a cure for Parkinson's disease or post-encephalitic Parkinsonism, but a procedure which, in carefully selected cases, offers a good prospect of relief from tremor. Cases of Parkinson's disease and post-encephalitic Parkinsonism vary a great deal from the classical syndrome (Parkinson, 1922). Physicians are only too familiar with the advanced case of paralysis agitans presenting

the fixed facies unmistakable tremor gross disturbance of gait cog wheel rigidity hyperptyalism and above all helplessness out of all proportion to any paresis which may be present Apart from avulsion of the auriculo-temporal nerves for the relief of the excessive salivation I believe surgery has nothing to offer these tragic cases On the other hand there are many patients where the only or outstanding manifestation is marked, disabling, and embarrassing tremor In the more fortunate cases one side only is affected The essential criterion for operation is that the patient should complain of the tremor as the symptom from which relief is desired and other effects of the disease should be at a minimum The patient selected for operation must have the mental capacity to co-operate in his rehabilitation The operation is well tolerated by elderly people and benign arterial hypertension is not a contra-indication

ANAESTHESIA

The technique of the anaesthesia is governed by several factors which include the poor physical condition of some of the patients the necessity for disconnecting the apparatus while the patient is being arranged in the prone position the acute flexion of the neck required by the surgeon and the frequent use of diathermy during the operation

Omnopon 20 mg ($\frac{1}{3}$ grain) and scopolamine 0 4 mg ($\frac{1}{150}$ grain) are given subcutaneously one hour before the beginning of the general anaesthetic Immediately before the induction of anaesthesia the patient s throat is sprayed with a solution of 10 per cent cocaine Induction is accomplished with a mixture of nitrous oxide oxygen and a little ether and then an acrylic tube size 9 or 10 is passed into the trachea through the mouth The throat is packed and the tube threaded through a London Hospital air way The mouth and face are covered with strips of adhesive elastic bandage and the tube is secured in place by means of strapping When the patient s position is satisfactory the tube is connected to the anaesthetic apparatus containing the usual carbon dioxide absorption unit The anaesthetic is continued with a combination of nitrous oxide and oxygen with the addition of a little ether or cyclopropane if the necessity arises Anaesthesia proceeds smoothly by this method. It is rarely necessary for the anaesthetist to compress the bag, the blood pressure and pulse rate remain steady throughout the operation and transfusion is not required

The first 8 cases showed signs of collapse within ten minutes of the beginning of the operation and this was thought to be due to the sudden change of the position of the patient combined with the effects of the adrenaline contained in the solution used for infiltrating the line of the skin incision Since the adrenaline has been omitted there has been no further trouble of this kind The effect of the adrenaline seemed to be confirmed by the fact that some of the early patients who had shown signs of shock did not do so when submitted to operation on the second side some months later when the use of adrenaline had been given up

THE OPERATION

Preparation of the Patient

The patient s eyes are protected by cotton wool held in place with adhesive elastic bandage The cerebellar position has been used in all cases but the

The author is indebted to Dr J Franklo for the detail regarding the method of anaesthesia

shoulder pieces have been omitted as they force the scapulae medially and thus interfere with the approach. To obtain adequate flexion of the head and neck four soft pillows are placed under the patient's chest.

Surgical Approach

The incision extends from the seventh cervical spine to the external occipital protuberance. In order to control bleeding pressure is applied to the skin edges by the assistant's fingers. The cut is extended through the deep fascia to which fine artery forceps are applied as to the galea aponeurotica in the case of incisions into the scalp. The weight of the forceps helps to control bleeding from the skin and superficial fascia. Vessels that continue to bleed are coagulated with diathermy. Absolute haemostasis is essential as even a small ooze of blood may completely obscure the site of the chordotomy. Thus the muscle fibres attached to the spine and laminae of the second cervical vertebra are detached by picking them up in small bundles by means of a fine plain-ended pair of dissecting forceps and by dividing them after the instrument has been touched with the diathermy electrode. The margins of the approach are separated by a "cerebellar" type of self retaining retractor.

Fig. 64. A No. 15 Bard Parker blade held in a pair of artery forceps 5 mm. from the end of the blade — used by the author.

The spine and laminae of the second cervical vertebra are removed by means of a double-action rongeur. Troublesome bleeding from extradural vessels is avoided by inserting patties (small pieces of lintine attached to lengths of fine black silk) between the bone and the dura mater while the bone is removed. The whole of the lamina is removed on the chosen side but very little of the lamina needs to be removed on the opposite side. Next the ligamentum flavum between the laminae of the second and third cervical vertebrae is stripped off the dura. The latter is then picked up with a sharp hook and incised longitudinally with a small round-ended tenotome. Several traction sutures are inserted along the edges of this incision. The arachnoidal membrane is punctured and torn to expose the spinal cord.

Chordotomy

A No. 15 Bard Parker blade is now clamped with a Halsted type artery forceps so that the blade projects 5 mm. beyond the beak of the forceps (Fig. 64). With the cutting edge facing towards the anterior aspect of the spinal cord the point of the blade enters the cord at the site of entry of a convenient posterior nerve rootlet. The blade is pushed into the cord as far as the end of the artery forceps and at an angle of 45 degrees (Figs. 65 and 66). The blade is swept outwards to complete

the chordotomy The extent of the cut can be checked by inserting a blunt instrument into the gap

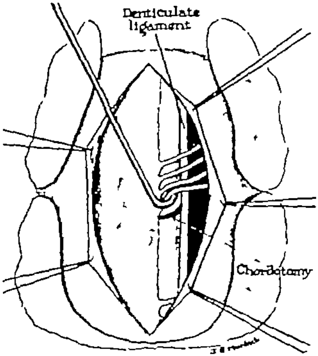

Fig 65 View of the posterior surface of the spinal cord showing chordotomy close to posterior spinal nerve root which has been retracted by means of a dural hook.

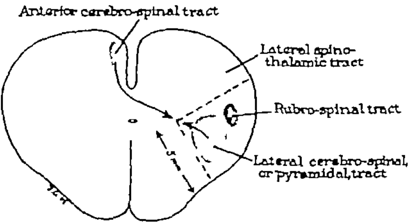

Fig 66 Cross-section of the spinal cord showing extent of chordotomy and performed by the author Note the encroachment on the lateral spino-thalamic tract

Closure of the Wound

The dura mater is now closed with interrupted fine black silk sutures on small round-bodied needles and the muscles are brought together in two layers with

thick silk. The skin margins are apposed by means of interrupted fine black silk stitches. The shortest operating time has been three quarters of an hour and the longest one and a half hours. Because the dura has been opened the patient is given an adequate course of penicillin.

MODIFIED OPERATION

The operation seems to be easier if part of the half laminae of the second and third vertebrae are removed on the selected side instead of the full width of the half lamina of the second vertebra (Fig. 67). According to the standard views of the position of the various tracts in the spinal cord the chordotomy which has just been described should divide the whole of the crossed pyramidal tract, the rubro-spinal tract and the posterior spino-cerebellar tract. Many of the patients who have had this chordotomy done have had patches of analgesia on the opposite side of the body showing that the lateral spino-thalamic tract has been slightly involved.

Fig. 67. Parts of the laminae of the 2nd and 3rd cervical vertebrae removed and edges of incision in the dura mater held apart by traction sutures to expose the spinal cord

The presence of these patches of loss of sensation should be regarded with satisfaction because they show that the operation will give the maximum possible relief from tremor.

POST-OPERATIVE COURSE

After operation there is usually an immediate but temporary hemiplegia. In most cases of unilateral Parkinson tremor and in many of the bilateral ones in which a chordotomy has been done on one side this paralysis passes off in a matter of days. On the other hand a few patients in spite of a thorough and convincing division of the lateral column have no detectable paresis. Some of the patients with bilateral tremor who have had a first stage operation (i.e. a unilateral chordotomy) have taken many months to regain substantial strength on the side which has been operated on.

Chordotomy has a definite though modest place in the treatment of Parkinsonism. The operation gives the best results in cases of unilateral tremor and is indicated in a small proportion only of the bilateral cases in which life is made impossible by the violence of the tremor. The second side should be done after an interval depending on the rate of rehabilitation and usually amounting to a period of several

months If a bilateral chordotomy is performed at one operation, restoration of function is likely to be difficult and prolonged.

Let it be stressed again that in the majority of patients gross disability is the outstanding feature and the tremor is a secondary consideration If chordotomy is undertaken for this the classical syndrome the patients will be made worse and the procedure will fall into disrepute

On the other hand, surgical interference does offer worth-while amelioration in those cases in which tremor is practically the only manifestation and the patient desires above all else to be relieved of the tremor When other effects of the disease are of tangible degree, such as paresis marked disability and emotional changes, the operation of chordotomy will only make matters worse

THE MANAGEMENT OF PARKINSONISM

A discussion of the use of drugs in this condition would be out of place in this account but there are points in the management of Parkinsonism of interest both to physician and surgeon The sufferer from Parkinson s disease becomes the object of excessive sympathy which can hardly be surprising when the symptoms are so obvious and distressing However there is nothing worse for these patients and nothing more likely to render them completely bedridden than this well meaning overindulgent kindness *The patients must always be encouraged to do as much as their remaining ability will allow no more and no less* The devotion of relatives is incredible but nothing is more pathetic than the patient who has been reduced to the level of a helpless pet in the family circle. Lassitude is one of the features of the generalized form of the disease and combined with the sympathy which the disease provokes, soon renders the patient completely helpless In most hospitals, patients spend too much of their time in bed Unnecessary rest in bed delays the recovery in most neurological diseases Patients should not require permission to get up but on the contrary should have to obtain permission to be in bed

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PART II

Thorax

CHAPTER 5

Congenital Defects of the Heart

WALTER MERCER

ONLY A FEW years ago congenital heart disease presented such a difficult therapeutic problem that once the diagnosis was established, the subject was closed No particular care was taken even to diagnose the type of lesion accurately because no treatment was possible The picture has changed considerably A surgical treatment for patent ductus arteriosus was developed and was first performed successfully by Gross Then, in 1945 Blalock and Taussig announced an operation for the relief of pulmonary stenosis and pulmonary atresia More recently Gross and Crafoord independently published reports of the successful surgical treatment of coarctation of the aorta Thus in only a few years time three of the most common congenital diseases of the heart have become amenable to surgical treatment Such progress merits the expectation that it will be possible in the future to attack surgically some of the other congenital heart lesions

PATENT DUCTUS ARTERIOSUS

DEFINITION

The ductus arteriosus is a vessel which runs between the bifurcation of the pulmonary artery and the isthmus of the aorta It is patent during intra-uterine life but normally closes after birth Patency of this ductus arteriosus is of vital importance in foetal life since it enables the enous blood entering the heart from the superior vena cava to pass directly to the aorta and thence to the placenta. This route is made necessary by the atelectatic state of the lungs and the consequent small size of the pulmonary vascular bed This short-circuiting action of the ductus arteriosus is no longer necessary after the child is born and the lungs expand, for then the lungs take up their permanent function of oxygenation of the blood and the blood takes its normal course through the expanded lungs (See Figs 68 and 69)

There does not yet appear to be any convincing explanation for the anatomical closure of the ductus, nor for its persistent patency In some cases it has been

shown that there is a physiological occlusion in most cases within five minutes of birth, possibly due to contraction of smooth muscle fibres in the wall set up by reflex action through the vagus. It may be that an alteration in the chemical constituents of the blood after birth may influence this contraction. The actual permanent or anatomical occlusion occurring in the first few months of life is more difficult to explain. Patent ductus arteriosus although commonly called so is not a congenital abnormality but a failure of closure after the child is born. It is possible that the inflation of the lungs and the angulation of the ductus arteriosus by the change in the position of the pulmonary artery may set the stage for the invading fibrosis that normally takes place whereby the ductus arteriosus is converted into a fibrous strand. If this fibrosis is deficient a patent ductus arteriosus results and if it is produced in excess coarctation of the aorta is produced by the overflow of the fibrosing process from the ductus arteriosus to the aorta.

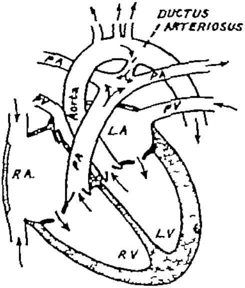

Fig. 61 Patent ductus arteriosus.

When the ductus arteriosus remains patent the patient is left with a shunt which is essentially an arterio-venous fistula. After birth, however, in such a case the blood flow through the shunt is reversed and the blood flows from the high-pressure aortic current to the lower one of the pulmonary artery. If this leak is small the abnormality may be well tolerated and there may be little incapacity. In many such instances indeed, the patients have lived to an advanced age. For many, however, there is no such happy outcome and for all there are risks and dangers, the greatest of which is a superimposed bacterial infection producing a bacterial endarteritis or later endocarditis. All patients, too, suffer in varying degrees from a lack of proper oxygenation of the blood and a consequent retardation in physical development. The leak puts an excessive strain on the heart and on the pulmonary and even the peripheral circulation, so that cardiac embarrassment or failure is common. Other and rarer complications occur, such as aneurysmal dilation of the pulmonary artery or ductus, and these have been known to end in rupture.

Although the outlook when viewed in early life seems good it is believed that the expectancy of life is about half the average

SYMPTOMS AND SIGNS

Limitation in Child's Activity

The condition is well tolerated in infancy and it is usually a surprise for the mother to be told that there is any abnormality in her child There is often however some limitation in the child s activity He may be easily tired rather prone to breathlessness on exertion and often his weight and muscular development are below normal As he grows these symptoms become more noticeable and towards adult life the

Fig 69 Patent ductus arteriosus.

fatigue becomes more troublesome and a reasonably active life less possible Occasional attacks of epistaxis occur and an unusual sensitivity to cold has been noted Cyanosis and finger clubbing do not occur

Heart Murmurs

The characteristic murmur described by Gibson in 1898 and since called the Gibson murmur is of the first importance in diagnosis It is systolo-diastolic in time and is best heard in the second left interspace close *to the sternum Its* best description is that which likens it to the sound in a machinery room but it has also been called churning the train-in-the tunnel sound or peals of thunder The murmur is localised in earlier life, but with the enlargement of the pulmonary artery to the left accompanied possibly by some aneurysmal dilatation the *murmur*

can be heard over a wider area and its maximum intensity further to the left of the midline It is important to know that in some cases this physical sign may be absent in infancy A basal systolic murmur may be heard about the age of 2 to 3 years and only at the age of 5 years or so does the typical murmur appear

Radiological Findings

Radiological examination (Fig 70) shows in the frontal view enlargement of the pulmonary artery This extends to the left as a semicircular shadow lying between the aortic knuckle above and the ventricular mass below Gross enlargement of the heart is uncommon and when present suggests some complicating factor such as an associated congenital abnormality or an infection of the ductus.

Fig 7 Radiogram of case of patent ductus arteriosus.

Blood Pressure

Blood pressure readings are of great diagnostic value In the first decade of life Gilchrist found that the pulse pressure I increased as a result of a fall in the diastolic level In the later age groups the systolic pressure increases, but the diastolic remains fairly constant A normal child under o years of age might have a blood pressure of 98 68 and pulse pressure of 30 while one with an open ductus would have a blood-pressure of 95 48 and a pulse pressure of 47 The larger the calibre of the ductus the lower will be the diastolic pressure

More important than these readings, however from the diagnostic point of view is the effect of exercise on them (Fig 71) Readings are taken after a simple exercise test such as 10 to 20 knee bends and it will be found that although the systolic pressure and the pulse rat may rise the haracteristic feature is a transient drop in

the diastolic pressure often nearly to zero and its prompt recovery in a minute or two. The enormous but transient increase in the pulse pressure is accompanied by tachycardia, bounding neck vessels and capillary pulsation.

Blood pressure readings after exercise are of particular value in diagnosis when the Gibson murmur is absent.

Electrocardiogram

An electrocardiogram is usually normal but this negative evidence is helpful in excluding other lesions. Any right axis preponderance makes one suspect some other lesion, particularly a pulmonic stenosis. Left axis deviation may be seen, however, in patent ductus arteriosus, especially in older patients who exhibit cardiac embarrassment.

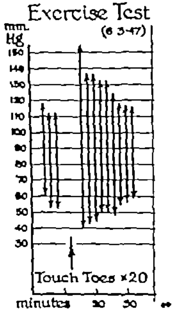

Fig. 71. The effects of exercise on the blood-pressure

COMPLICATIONS

Infection

The most serious complication of the condition is infection occurring first as an endarteritis of the pulmonary artery and spreading, it may be, to the heart or along the ductus to the aorta. The high pressure jet of blood from the ductus damages the opposite intima and an atheromatous patch develops. On this patch organisms are caught. Almost invariably the infecting organism is the *Streptococcus viridans*. Although this infection may occur in the younger patient, the highest incidence is found in those of the third and fourth decades. The complaints are high fever, sweating, loss of appetite and other symptoms of a general septicaemia. Haemoptysis and chest pain occur from infarcts into the lung. Peripheral emboli are, of course, uncommon. Blood cultures prove the presence of this complication and give some evidence of its severity. An x-ray shows prominence of the pulmonary artery, progressive cardiac enlargement and a patchy consolidation throughout the lung

fields advancing and subsiding in successive pictures The clinical diagnosis of the infected case is based on evidence of septicaemia, local signs of a patent ductus and a patchy consolidation throughout the lungs advancing and subsiding as fresh emboli are shed from the vegetation in the ductus or pulmonary artery

Cardiac Enlargement

The strain put on the heart is proportional to the volume of the leak The blood shunted from the systemic circulation into the pulmonary artery raises the pressure in the pulmonary circulation and in that way increases the pressure at which the right ventricle must work. The greater the volume of the leak and the greater the rise of the pulmonary pressure the greater is the strain on the right ventricle and on the pulmonary artery proximal to the ductus arteriosus Usually the pressure in the heart is small and the heart is but slightly enlarged In some cases, however there is considerable cardiac embarrassment with ventricular hypertrophy and this may be severe enough to lead to heart failure

Other complications such as aneurysmal dilatation of the ductus or the pulmonary artery have been reported but are rare.

PROGNOSTIC CONSIDERATIONS

The mortality rate of operations in uncomplicated cases in children is less than 5 per cent and the risks are so negligible that it is probably wise to advocate operation during the childhood period even though the children are symptom-free at the moment If not operated on their life expectancy is considerably less than normal possibly as low as 50 per cent and of those who survive most will suffer from impaired general efficiency cardiac embarrassment or at any rate serious fatigue Further the operation is a much more serious one in later life owing to the greater difficulty in exposure greater difficulty in freeing the vessels owing to *surrounding adhesions and greater rigidity of vessels The ductus tends to become* shorter in later life and with the growth of the neighbouring great vessels there is less room to work upon it. In the second and third decades there is already some arterio-sclerosis of the ductal walls which predisposes to tearing of the coats when ligatures are applied It is to be recognised therefore that in the absence of complications the older the patient the greater the risk and the more definite must be the indications for operation

After the age of 20 the patient s disability must be more severe to justify operation Should symptoms become more severe or congestive heart failure threaten or appear then ligation should be recommended A failing heart in this form of heart disease usually runs a downhill course under medical treatment and so surgical measures even though the risks are considerable seem justified In the presence of an infected ductus operation is the treatment of choice and should be undertaken immediately after the institution of penicillin therapy Special indications according to Taussig are stunting of growth great cardiac enlargement low diastolic pressure threatened cardiac failure rheumatic heart disease superimposed upon a patent ductus and subacute bacterial endocarditis She does not think septal defects necessarily contra indicat operation, but if there is clubbing or cyanosis and if the continuous murmur is absent then operation should not be undertaken

THE OPERATION

Pre-operative Treatment

The cardiac reserve if low should be improved with digitalis. The possibility of an active rheumatic infection should be excluded. The patient should be free of any nasal, dental or respiratory infection and all of these should be most carefully looked for. The possibility of a right aortic arch must be considered but the physical signs will make this obvious. The child should be admitted to the surgical ward some days before operation to get him acclimatised and allow him to know those who will look after him. Penicillin is given for thirty-six hours beforehand. His blood is typed, a supply is procured and an infusion is started before the operation to meet the contingency of sudden haemorrhage during the operation.

The Technique of Operation

The anterior approach has been given up by the writer in favour of the posterior one because of the wider operative field, the greater accessibility of the mediastinal structures and the greater control of the ductus in case of haemorrhage. In older patients the ductus lies further back and an anterior approach is not adequate.

Posterior Approach. The child lies on his right side and to steady him the right knee is fully flexed and the left extended. A long strip of elastoplast is placed across his pelvis and to the sides of the table at this level. This ensures such stability of the patient that the position does not change. The left hand is fixed up to the top of the table, so elevating the scapula out of the way.

A long oblique incision (Fig. 72 a) is made from about the third spinous process in the midline and going downwards laterally and forwards, crossing the lower angle of the scapula, to the anterior axillary fold. This incision passes through the skin and deep fascia and exposes the muscles. The more superficial muscles—the trapezius and latissimus dorsi—are divided in the line of the incision and, at a deeper level, the rhomboideus major and the serratus anterior are divided and bleeding points sealed with diathermy. The scapula can now be mobilised and the hand inserted under it, the ribs counted accurately, and the fourth rib localised. This rib is now resected subperiosteally from its vertebral attachment to the anterior axillary line. The removal is subperiosteal so that re-formation may take place and prevent any scoliosis later.

The deep layer of periosteum is now divided and the chest cavity opened. Any adhesions between the lung and the mediastinum are divided and the lung is allowed to collapse. Should the exposure be considered inadequate, as happened for example in a case of scoliosis with the concavity to the left, the third and fifth ribs may be divided at their spinal ends. A self-retained retractor is now inserted and opened. A wide exposure is ensured and the scapula is displaced and retained out of the way.

The lateral aspect of the mediastinum is now open to view and the phrenic nerve and the aortic arch can be seen. Behind the former and below the latter a finger palpates the region of the ductus and the vessel is easily and accurately located by the characteristic thrill which can be abolished by pressure. With this point as its centre a vertical incision of 5 to 6 cm. is made behind and parallel to the phrenic nerve (Fig. 72 b). A stay suture is put on the anterior cut edge of the mediastinal pleura when it is swabbed clear of the underlying tissues. A pledget of wool on forceps is useful now in clearing the front of the ductus from its surrounding areolar

tissue At this stage care must be taken lest there be an aneurysmal dilatation of the pulmonary artery which would extend up over the front of the ductus This must be carefully dissected and swabbed down to ensure a good exposure. By clearing the posterior flap of pleura the vagus nerve is made visible and its recurrent branch traced downwards (Fig 72 c) As this is done the branch will be seen to wind round the ductus so determining where the ductal dissection will start

Encirclement of the Ductus (Fig 73) For the encirclement of the ductus the safest instrument is a pair of forceps rather like cystic duct forceps They have a blunt nose and no teeth on the end I use a series of four the acuteness of the curve varying in each so that one is enabled to burrow at the appropriate angle round the ductus The long handles give good access and good control. The forceps are insinuated first in the angle between the ductus and the aorta below the ductus

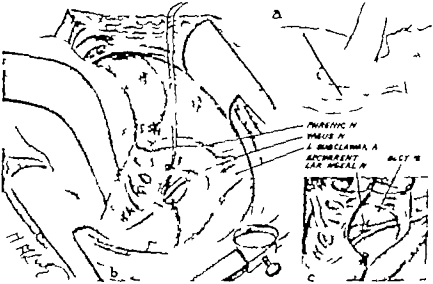

Fig 72 The operation for patent ductus arteriosus.

The skin incision
b The incision in the mediastinal pleura
The exposure of the recurrent laryngeal nerve and the ductus coming into view

following but avoiding, the recurrent branch of the vagus nerve By alternate insertion and opening the forceps are passed gradually further and further around When this route has been made as far as conveniently possible a start is made from the proximal angle of the aorta and ductus The posterior junction of the two channels is the most difficult part as often there is a pretty firm attachment of the ductus to the bronchus and often the two dissections seem to be in different lines of cleavage In the cases complicated by infection it is particularly necessary at this stage to proceed slowly for the adhesions here are more firm and impenetrable and the ductus itself is more friable This procedure demands patience and perseverance It is helpful to have the pulp of the index finger at one end as a guide using it as a target on which to project the forceps With this finger one can feel whether or not the forceps are clearing the ductus from the thickness and fixity of the struc

tures between the instrument and the finger Areolar tissue will be felt in the one case and the ductal wall in the other Once the fully curved forceps are around the ductus and the blunt nose is visible at the other side the channel behind the ductus may be enlarged by opening up the forceps

Obliteration of the Ductus To ensure obliteration of the ductus several methods are in use varying from the old fashioned simple central ligature to division of the vessel and stitching of both ends as advocated by Gross It seems curious that a vessel destined by nature to close is so recalcitrant when given every encouragement by operation Yet this is so and recanalisation of the ductus has occurred in an appreciable number of cases This probably occurs where the blood pressure is high and the ductus balloons out on either side of the ligature The dilatations make contact and adhere Thereafter the ligature erodes through and a new canal is formed It is to prevent such a happening that Gross suggests division of the ductus

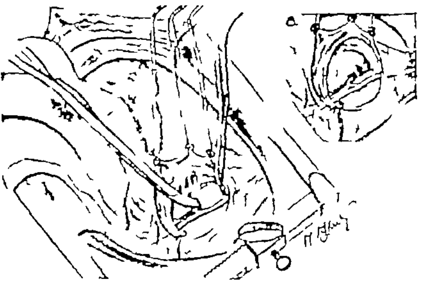

Fig 73 The operation showing the encirclement of the ductus preparatory to the passage of the ligatures. The ligatures tied.

Blalock places purse-string sutures at the two ends of the ductus two through-and through mattress sutures of silk between the purse-string sutures and a ligature of umbilical tape on the middle

A certain and a simple method is to obliterate the ductus over a reasonable length close to its aortic end There is then little dilation at either side of the ligature since on the pulmonary end the pressure is not high enough and on the aortic end the walls do not permit it Two strands of No 5 Chinese twist silk are used one of them being coloured (usually by dipping in the brilliant green antiseptic used for sterilising the skin) to distinguish it from the other when the knots are tied Surgical knots are tied in both as close to the aorta as possible and as tightly as possible carefully avoiding the recurrent nerve The ends are left rather long If the extent of the ductus closed by the sutures seems short, one or more additional sutures are tied around the ductus to obliterate more of the vessel Penicillin is

applied to the area but the mediastinal pleura is left open The chest is now closed in layers using silk stitches A catheter is left in the chest at the posterior end of the wound up to the last moment before closing to allow the anaesthetist to inflate the lung No drainage is used The child is put in an oxygen tent and remains in it for about two days The blood drip is removed on the day of operation and luminal or heroin is used to keep the child comfortable and well sedated A radiogram is taken the following morning and on the few occasions when needed, the chest is aspirated

Results of Operation

Changes in Blood Pressure After surgical closure there is no important change in the systolic pressure but the diastolic shows an immediate rise (Fig 74) This is

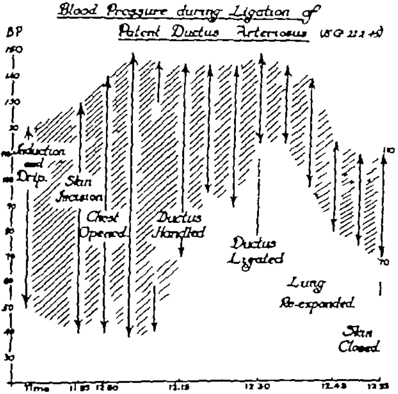

Fig 74 The blood pressure during and after the ligation

evident on the operating table as soon as the ductus is tied This rise in the diastolic pressure is interesting and seems to indicate that the operative manipulations cause a contraction of the muscular tissue present in the ductal wall With the stethoscope routinely employed at operation one can observe the typical murmur before ligation and its complete disappearance after the ductus is ligated. Some observers have described a typical murmur but of lessened intensity after tying but this must indicate imperfect closure of the leak and would be an indication for further ligation and tighter knotting

Heart The activity of the heart is lessened as shown by the diminution of the

forcefulness of the apex beat The pulsation in the neck too is less obvious Teleradiograms show changes in the cardio-thoracic ratio It would appear that in cases of hypertrophy in the growing child the heart size remains stationary while the body grows and so the normal ratio is restored When enlargement is primarily a dilatation the heart will shrink rapidly after closure of the ductus

General Appearance Patients with retarded physical development show a rapid gain in weight A an example a boy of 13 a debilitated child with a fairly big heart gained 43 pounds in weight and 8 inches in height in the two years subsequent to ligation Perhaps the best assessment may be obtained from the general clinical impression based on the patient physical state sense of well being freedom from symptoms, and capability for exercise supplemented in the case of a child by the opinion of the mother

The Effects of Operation in the Case Complicated by Infection

Within a few minutes of ligation of the ductus in a case which has previously yielded profuse growths of streptococci the blood stream becomes sterile (Fig 75)

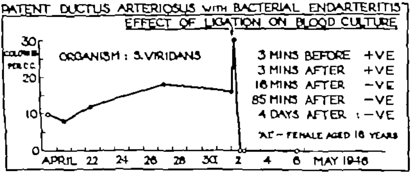

Fig 75 The effect of ligation on the blood culture in an infected case

One case showed 18 colonies of *Streptococcus viridans* before operation 30 colonies three minutes after ligation and no growth sixteen minutes after or in subsequent cultures Ligation apparently sterilises the blood stream more quickly and more effectively than penicillin probably because the abrupt exclusion of arterial blood from the pulmonary artery provides a venous environment of such low oxygen content that the streptococcus cannot survive The high-tension jet dislodging bacteria from the vegetation is stopped and the current in the pulmonary artery quiets down and allows healing of the vegetations

The most successful cases treated by ligation are those in which the infection is limited to the pulmonary artery Late stages of infection imply the likelihood of a spread of the vegetations to valves of the heart possibly by way of the ductus to the aorta This is usually recognised by the presence of peripheral rather than the usual pulmonary emboli and in these cases it is doubtful if operation should be advised and certainly not before adequate treatment by penicillin. While it is recognised that penicillin will cure many cases of endarteritis the cure may not be permanent in the presence of a persistent patent ductus Surgical ligation will still be necessary for cure and the only difference is in its timing

Complications of the Operation

Inability to identify the ductus has been described but in an uncomplicated case correctly diagnosed there should be little difficulty It can be palpated and its thrill felt, and the anatomical landmarks—phrenic nerve aortic arch and vagus nerve—are easily located From the last of these the recurrent laryngeal leads one to the abnormal vessel

Haemorrhage is more likely to take place in the case complicated by infection. In this type of case the walls are friable and adherent to the surrounding areolar tissue The dangerous area is at the back where the dissection must necessarily be blind It is safest to make this dissection almost on the aorta itself just close to the ductus, or where possible under the ad entitia of the aorta as advised by Touroff In one case in which I anticipated difficulty in dissecting the ductus since an attempt had been made to close it elsewhere it was suggested that the approach should be behind the aorta. The aorta would be dissected clear as is done in a coarctation and the ends of the silk passed down from above behind the aorta one end proximal to the ductus the other distal In the particular case for which this was thought of however there was no difficulty in getting the ligatures around the ductus

Sepsis and *pneumonia* are prevented by penicillin and combated by the same drug when they occur *Injury to the recurrent laryngeal nerve* is avoidable if the dissection is carried out with care

Incomplete occlusion should not occur If it does it will be recognized at once if a stethoscope and sphygmomanometer are used in every case A Gibson murmur will still be present and there will not be a satisfactory rise in the diastolic pressure A further and tighter ligation is done at once

Prognosis

The mortality rate in uncomplicated cases is under 4 per cent, but in cases with infection it is higher but should be under 15 per cent Recanalisation will occur in about 5 per cent of instances unless di ision of the ductus has been the operative method of closure It is probable that di i ion of the ductus will result in higher mortality figures unless it is carried out by a very experienced operator and only in selected cases

THE TETRALOGY OF FALLOT

DEFINITION

The commonest cause of cyanosis in congen tal heart anomalies is the tetrad or tetralogy of Fallot The four main features are tenosis of the pulmonary artery dextra-position of the aorta so that it overrides the septum a high interventricular septal defect, and right entricular hypertrophy If a child with this condition survi es it is a blue baby cyanotic with little or no exercise tolerance with clubbed fingers or toes and with typically a preference for the squatting position.

The defects in the tetralogy of Fallot are probably the result of a de lopmental error in the separation of the truncus conus channel into two separate vessels the pulmonary artery and th ascending aorta

THE NATURE OF THE MALFORMATION

The pulmonary stenosis usually involves both the pulmonary artery and the pulmonary conus of the right ventricle (Fig 76) Dextra position of the aorta means that the aorta, although it rises from the left ventricle overrides the ventricular septum and receives some blood directly from the right ventricle A high interventricular septal defect is the inevitable result of the overriding of the aorta The direct consequence of the dextra position of the aorta is a persistent venous-arterial shunt Right ventricular hypertrophy results from the increased work demanded from the right side of the heart. This is due to the fact that with each cardiac cycle all the blood from the left ventricle and that portion of the blood from the right ventricle which is pumped into the aorta is returned to the right auricle and then to the right ventricle Owing to the pulmonary stenosis there is

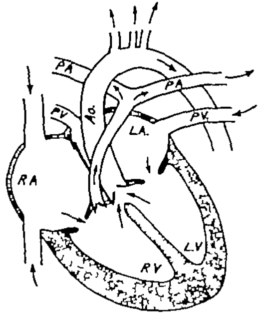

Fig 76 The tetralogy of Fallot

difficulty in the expulsion of blood from the right ventricle Blood must be pumped either through the stenosed pulmonary artery or into the systemic circulation Both these factors increase the work of the right side of the heart.

THE CLINICAL PICTURE

Cyanosis and Clubbing of the Extremities

The typical case of tetralogy is best exemplified by a child of 5 to 10 years of age who is cyanotic and displays the secondary manifestations of cyanosis—that is, clubbing and polycythaemia—who experiences dyspnoea on mild exertion in whom a systolic murmur can be heard, who has a boot-shaped heart and in whom an electrocardiogram shows marked right axis deviation The outstanding features are intense cyanosis and clubbing of the extremities combined with a heart of normal size In early infancy the syndrome may not be distinctive because so long

as the ductus arteriosus remains open blood not only flows directly from the pulmonary artery to the lungs, but also from the aorta through the ductus arteriosus to the lungs During the first few weeks of life there may be no visible cyanosis Sometimes it is not until the infant begins to walk that this becomes apparent. But if cyanosis does not appear until the ductus has closed it means that the stenosis is less extreme and the prognosis is probably rather better

The intensity of the cyanosis varies with the reading of the haemoglobin and the percentage of reduced haemoglobin in the blood, this depending upon the degree of stenosis If this is extreme there is barely enough oxygen to meet the require ments of the body and even slight exertion causes dyspnoea Clubbing of the extremities develops as a result of the persistently poor oxygen saturation of the arterial blood and the compensatory polycythaemia, which varies with the intensity of the cyanosis and the percentage of the available haemoglobin

Blood Studies

Polycythaemia is usual and the blood cell count is generally between 6 and 9 million and may be even higher The haematocrit reading is also high frequently between 60 and 80 Oxygen saturation of the arterial blood is low If the child can walk only a few feet it is usually down to about 30 or 35 per cent and when it drops to 20 or 25 per cent the child is seldom able to walk. The child s exercise tolerance is therefore limited and dyspnoea on exertion is common and is accompanied by an abrupt fall in both the oxygen content and the oxygen saturation of the arterial blood

Habitus, etc.

Squatting is a common habit among cyanotic children who suffer from inadequate circulation to the lung They appear to be able to breathe more easily in this position Some even sleep with their knees bent up on their abdomen As a result of the inadequate supply of oxygen to the body there is commonly stunting of growth, and the children are thin have difficulty with their digestion and put on weight slowly Puberty is often delayed

Cardiac Findings

The heart is strikingly small The right entricular wall however is hyper trophied The right ventricle may become enlarged and press on the chest wall and cause some chest deformity The heart action is forceful Usually there is a thrill over the base of the heart A murmur occurs even more constantly than does a thrill This is systolic in time and is heard along the left border of the sternum but is not transmitted to the essels of the neck If the pulmonary stenosis is extreme there may be no murmur *The pulmonic second sound is weak but the aortic* second sound may be so loud and the aorta displaced so far to the left that the closure of the aortic valve is better heard to the left than to the right of the sternum

X-ray Findings

The heart is usually characteristically boot shaped, the upper margin of the cardiac silhouette to the left of the sternum being conca e in contrast to the normal convexity (Fig 77) A right aortic arch is relati ely common, occurring in about

25 per cent of all cases of tetralogy. When the aorta arches to the right the aortic knuckle is frequently visible to the right of the sternum within the shadow of the superior vena cava. Even when the x-ray examination does not show the aorta on the right, upon delineation of the oesophagus by a barium swallow the oesophagus is seen to lie to the left of the great vessel. Under such circumstances, if pressed upon by the aorta, the oesophagus is dilated to the left and indented by the aorta on its right margin. The hilar shadows in the lungs may be increased by an extensive collateral circulation.

DIAGNOSIS

The diagnosis is based upon the finding of marked clubbing and cyanosis in combination with a heart usually of normal size. Generally a basal systolic murmur and

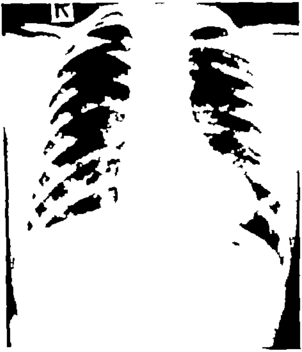

Fig. 77. Radiogram in case of congenital pulmonary stenosis.

thrill are present. Both are louder in the recumbent position. The second sound to the left of the sternum may or may not be accentuated. X-ray shows a concave curve at the base of the heart to the left of the sternum due to the absence of a normal pulmonary conus. There may or may not be a right aortic arch. The electrocardiogram always shows a right axis deviation.

COMPLICATIONS

The two chief complications are thrombosis and subacute bacterial endocarditis, the former, of course, being due to the polycythaemia.

THE OPERATION

The operation which has been designed for the tetralogy of Fallot increases the circulation to the lungs. The object is to increase the pulmonary blood flow and

remove the stimulus for the development of polycythaemia and to *permit the* patient maximum activity without placing undue strain upon the heart. Experience has shown that this is obtained when there is an oxygen saturation of the arterial blood of approximately 80 per cent The essence of the operation is the creation of an artificial ductus arteriosus by the anastomosis of an arterial vessel to the pulmonary artery The systemic vessel must have a higher blood pressure than the pulmonary artery so that the blood will flow into the pulmonary artery

Criteria for Operation

Dr Taussig has laid down four conditions that must be met in order that the operation may be successful

1 The main difficulty must be lack of adequate circulation to the lungs This is a *sine qua non* and can be determined by a physical examination and x ray although occasionally laboratory tests are necessary

2 *The heart must be such that it can adjust itself to the altered circulation. This* must be presumptive.

3 There must be a pulmonary artery to which to anastomose the systemic artery and the pulmonic circulation in the opposite lung must be such as to survive the temporary occlusion of one artery during the time required for the anastomosis

4 The pressure of the two circulations must be such that the blood will flow through the new artery to the lung

The last two points cannot be determined by a simple clinical procedure and may in certain cases be determined only after the chest is opened Clinical evidence pointing to an inadequate circulation in the lungs lies in the cyanosis dyspnoea, *squatting and reduction of the oxygen saturation of the arterial blood The inade*quate circulation is diagnosed on x ray examination by the shape of the heart the diminished hilar shadows and the absence of pulsation at the hilus of the lungs

Indications for Operation

The operation is indicated in all those who are severely handicapped and those who have little to lose and in whom the outlook is poor and who are likely to die *should nothing be done The mortality rate in infants and adults is higher than in* children Operation is usually not wise until the child is over 2 years of age but it should be *done before he reaches* adult life The most suitable age appears to be between 5 and 12 years as it is not known whether the vessel anastomosed in infancy will increase sufficiently in size as the infant grows to maintain adequate circulation to the lungs However it is hardly justifiable to let a baby die of anoxaemia while waiting for him to reach the more favourable age The severity of the *pulmonary stenosis can be estimated by the oxygen saturation of the arterial blood* and the extent and rapidity of the fall with exercise A marked reduction of the pulse pressure with exercise indicates that the pulmonary blood flow is extremely meagre The extent of the polycythaemia and the haematocrit reading are taken into consideration An extreme concentration of the blood markedly increases the danger of thrombosis.

Finally it should be remembered that if operation is to be undertaken the heart *should not be enlarged* there should be no fulness of the pulmonary conus and no pulsation in the lung field Minor objections that might be considered

contra indications in general surgery should not be so considered here although of course all upper respiratory infections should be cleared up

Principles of Operative Treatment and Selection of Cases

The possible methods by which the blood supply to the lung may be increased in cases of pulmonic stenosis are many Blalock classifies them as

1 A systemic vessel to the pulmonary artery end to side
2 A systemic vessel to the distal end of a divided pulmonary artery
3 A systemic vessel to the proximal end of a divided pulmonary artery
4 The aorta to the pulmonary artery side to side (Potts operation)
5 The aorta to the main pulmonary artery in the mediastinum
6 An operation on the stenosis itself something after the nature of a valvotomy

Choice of the Vessel to be Used for Anastomosis The choice of the vessel that is to be used for the anastomosis requires some consideration First it must be determined whether the aorta is on the right or the left side the latter being the normal position If it is on the right side which it is in approximately 25 per cent of all cases of tetralogy then probably the anastomosis should be done on the left side and the subclavian branch of the innominate used to carry out the anastomosis Potts operation may be very difficult on this side since the pulmonary artery is at a low level. If the arch is left-sided the normal the main choice lies between a right sided subclavian branch of the innominate into the right pulmonary artery or a left-sided aortic-pulmonary artery anastomosis after the manner of Potts Potts operation will probably be the choice in the younger child since it permits the anastomotic opening to be made as large as needed to pro ide adequate blood circu lation to the lung although actually there is a maximum since, if it is made too large cardiac failure may result when the anastomosis is opened up In a child of 2 to 4 years of age the opening in the aorta should be about $\frac{3}{16}$ inch. If it is much less it is liable to fibrose up while if it is much more, cardiac embarrassment may result from the greater effect on the heart

In the slightly older child from 5 to 12 years the subclavian branch of the innominate is probably the most satisfactory vessel for anastomosis After the age of 12 years the left subclavian may be used instead of the subcla ian branch of the innominate (see Fig 82) Its point of origin from the aorta is nearer the pulmonary artery than the bifurcation of the innominate on the other side and angulation is less likely to take place Occasionally when the left subclavian branch of the artery is anastomosed in young children it seems to angle acutely at the aorta itself lessening the blood flow through it. When a branch of the innominate artery is used an end to-side anastomosis is done but it is necessary in some cases to do an end-to-end e g where the pulmonary artery itself is placed too far distally from the subclavian branch of the innominate as may occur in the right side so that anastomosis will produce angulation or where it is too small for an end to-side anastomosis, and occasionally where troublesome bleeding has been encountered behind the pulmonary artery during the course of dissection In such cases it may be wise to divide the pulmonary artery and anastomose either its distal or its proxi mal end into the subclavian preferably the distal end into the distal end of the cut subclavian (see Fig 83)

Anomalous Anatomy

Various other anomalies which may be quite disturbing may be found at this operation. It is important to remember that there may be a pulmonary artery to one lung only the other being absent Thus it is wise to occlude the pulmonary artery for a few minutes at operation to see the effect upon the patient, since if there is no artery on the other side it will soon be obvious that the operation can not be carried out, as the patient cannot live without the pulmonary circulation long enough to complete the anastomosis It is interesting, however that in one case the single artery was occluded for ten minutes before the patient was affected

The pulmonary artery is occasionally very small and lying posteriorly and inferiorly to the vein It is quite possible to mistake the pulmonary vein for the artery and to *anastomose a systemic vessel to the vein. If such an anastomosis is carried out then* death results as has been described by Blalock. This mishap may possibly be obviated by tracing the pulmonary vessel into the pericardium

Another complication is the early proximal division of the pulmonary artery into its branches, as does occasionally happen very close to the pericardium and in such cases it is not possible to complete the operation unless there is one particularly large branch that is adequate for an end to-end anastomosis

The origins of the great vessels from the aortic arch are also subject to great variation The subclavian artery may arise in the aortic arch before the carotid artery or both carotids may arise from the common trunk The right subclavian may come from the left side of the normal arch and may even pass behind the oesophagus and produce a form of oesophageal dysphagia The pulse of the carotid artery should always be palpated after the vessel which is to be used for the anastomosis has been isolated and occluded, but before it has been severed Occasionally a left superior vena cava is found and of course bilateral superior vena cava is recorded *in anatomical literature*

Preparation for Operation

If the heart is weak it is a good practise to give digitalis for some time before operation

Fluids should be administered liberally especially on the morning of the operation so that the child is not dehydrated

Systemic penicillin therapy is begun before the operation

On the morning of the operation an intravenous needle is inserted into a leg vein and connected by a Y-connection to separate containers of blood and plasma. The blood is kept in reserve with the tube clipped but ready to be turned on instantly in case of haemorrhage The plasma is given as a continuous infusion throughout the operation and the speed of delivery is varied in accordance with the patient's blood-pressure Every effort is made to keep up the blood pressure to prevent cerebral thrombosis Atropine may be given during the operation if the pulse *becomes unduly low*

The Technique of Operation

Anaesthesia Cyclopropane is used as an anaesthetic and controlled respiration is considered to be most important since it is so much less tiring for the patient

Position of the Patient The patient is placed on hi left i le with his right arm pulled up toward the head so tilting the scapula The pelvis is fixed with elastopla t strapping on to either side of the tabl The head of the patient is tilted towards the side of operation to diminish traction on the branches

Surgical Approach An Inci ion is made from the second pinous process down ward and forward to the edge of the ternum and across the lower angle of the scapula The chest is entered after subperiosteal resection of the fourth rib A good view of the area of operation is obtained and the possibilities are now considered and the anatomical structures reviewed The azygos vein is divided between liga tures as this allows a better exposure of the pulmonary artery Dissection of the pulmonary artery is carried out until it is pretty freely mobilised up to the peri cardium It branches are also freely mobilised to give as long a free length as possible (Fig 79) At this stage this artery is temporarily occluded and the effect

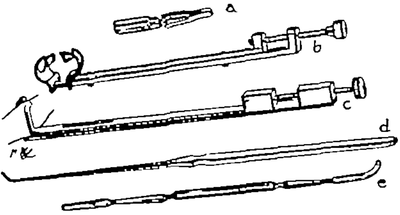

Fig 78 The instruments used in the operation.

Bull-dog lamp.
b Modification of Potts clamp
Blalock occlusion lamp
d Used fo retraction of the essel wall in suturing the first row

on the patient is observed in case there is no similar vessel on the opposite side Dissection is now carried beneath the superior vena cava and the aortic arch and the innominate branch of the latter is identified. This vessel is followed distally to its branches The dissection may be facilitated by encircling the innominate with a piece of tape The subclavian may be located by the vagus and the recurrent branch in its vicinity After these structures are identified the mediastinal tissue may be dissected with greater freedom

Mobilisation of Arteries The subclavian, carotid and innominate arteries are mobilised as far as possible in order to allow good co-aptation for the anastomosis A Blalock clamp is now applied to the subclavian artery at its proximal end and the two ends of the rubber tied together to ensure a firm grip without slipping (Fig 80) A ligature is then placed just distal to where a large branch is given off and the branch itself is ligated It is divided just proximal to the ligature and across the exit of its branch so giving a larger calibre of vessel for anastomosis Where

there is difficulty in getting the subclavian down to the pulmonary artery the carotid is freely dissected This allows a further downward displacement of the subclavian If this co-aptation is still difficult the pulmonary ligament on this side may be divided This loosens the pulmonary artery and allows it to come up more easily The end of the subclavian is freed of adventitia to prevent its being caught in the suture and causing constriction of the anastomosis It is well to give the patient a rest at this stage and allow the lung to be inflated

The pulmonary artery is now examined When it is fully mobilised it is occluded proximally with a Blalock clamp and at its distal end a silk ligature is placed twice round it for traction and occlusion. More length may be obtained if the branches

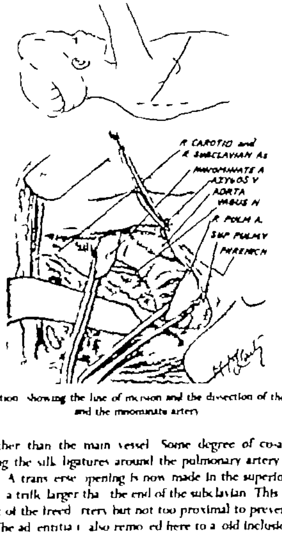

Fig 74 The operation showing the line of incision and the dissection of the pulmonary artery and the innominate artery

are encircled rather than the main vessel Some degree of co-aptation may be secured by pulling the silk ligatures around the pulmonary artery up towards the subclavian artery A transverse opening is now made in the superior surface of the pulmonary artery a trifle larger than the end of the subclavian This is made towards the proximal part of the freed artery but not too proximal to prevent its ligation in case of trouble The adventitia is also removed here to avoid inclusion in the suture line The two Blalock clamps allow adequate control of the vessel for suturing and are preferable to the bulldog clamp which is sometimes used

The Anastomosis The anastomosis is now performed between the end of the subclavian and the side of the pulmonary artery using 5 O silk on an atraumatic

curved needle (Figs. 81 and 82). The suture is a continuous everting stitch approximating the two vessels together. It is a series of mattress stitches. The *posterior* row is placed along its whole length but left loose until this row is completed and only then pulled taut. This allows better access for putting in the stitches. Stay sutures are then placed at either end to anchor the continuous suture and prevent any degree of purse-string effect which might of course produce some constriction. The anterior row is completed by using a similar type of stitch although a simple continuous over-and-over stitch is quite as good.

This part of the anastomosis is usually easier than the posterior row. The distal pulmonary occlusive silk is removed first, then the proximal clamp, and during all

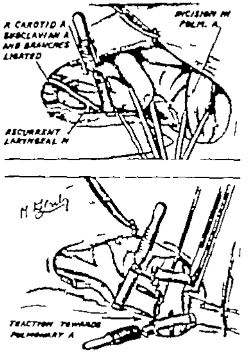

Fig. 80. The operation. Further dissection of the vessels and the clamps applied. A Blalock clamp may be used on the subclavian artery and silk round the pulmonary artery distally. When the bull-dog clamp is used on the subclavian, silk may be used to pull it down to the pulmonary artery as shown.

this time a wet swab is kept on the suture line until the pulmonary artery has completely opened up, and for some time afterwards. This allows any slack in the suture line to be taken up by the expanding vessel. The swab is then momentarily removed and if there is no more than slight oozing it is reapplied. When this is satisfactory the subclavian clamp is slowly loosened and the effect watched. There may be a slight ooze from the suture line on removal of the occluding devices but this usually stops with sponge pressure. If there is a considerable leak it can be arrested with an additional suture. Fibrin foam is useful if the leak is persistent. Unless the leak is a spout the foam rarely fails to stop it. No attempt is made to close the opening in the mediastinal pleura, but penicillin or streptomycin if

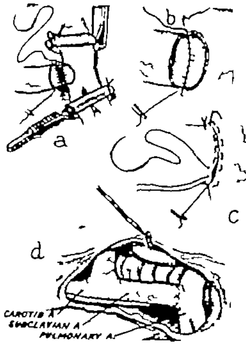

Fig 81 This shows the method of stitching the vessels.

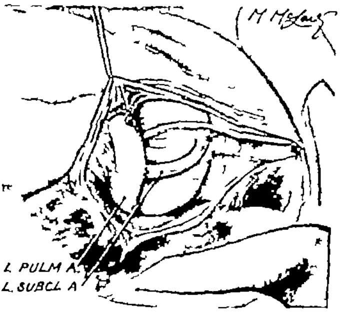

Fig 82 The subclavian artery used on the left side. It tends to be smaller and angulation is apt to take place.

available, is placed in the wound and the chest sutured in the usual manner, care being taken to see that the lung is fully expanded by the anaesthetist before the final stitches are inserted. After the chest is closed air is aspirated with an artificial pneumothorax apparatus. This helps lung expansion.

In the original article by Blalock and Taussig the suggestion was made that it might be possible to anastomose the aorta to either the right or the left pulmonary artery depending on whether the aorta is normal or right sided but this procedure was never used because it was obvious that an essential step in the operation would be temporary occlusion of the aorta with its attendant risk of paralysis from anoxaemia. A lesser objection was that suture would be difficult on account of the friability of the aorta and the discrepancy in the thickness of its wall and the wall of the pulmonary artery. The second objection still remains but the first has been obviated by an ingenious clamp designed by Potts of Chicago by which the aorta may be partially occluded while a side-to-side anastomosis is performed.

Though this operation can be utilised for patients of any age its greatest usefulness will be in small children, in many of whom the aortic branches are very small.

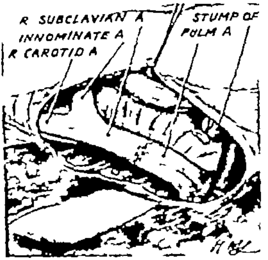

Fig 83 The subclavian in certain cases may be sutured to the divided pulmonary artery in an end-to-end manner

Technique of Aortic Pulmonary Anastomosis (Potts)

This operation (Fig 84) is of course carried out on the side of the aortic arch. In the normal left-sided arch the author uses a postero-lateral approach. The child lies on its opposite side and the chest is approached by removing the fourth rib from near its vertebral bed to the anterior axillary line. Should more room be required it is easy to divide the rib above and below to obtain a wider exposure. The pulmonary artery is dissected and as long a segment as possible is mobilised and probably a little longer than is necessary in the ordinary Blalock type of operation. It is then occluded for a few minutes to determine the patency or otherwise of the opposite pulmonary artery. One and a half inches of the distal part of the arch of the aorta is completely mobilised after ligation and division of all its bronchial and intercostal branches. Silk ligatures are passed round the distal and proximal extremities of the mobilised segment of the pulmonary artery. Each ligature is placed round twice but not tied. A Potts type of clamp is applied to the mobilised portion of the aorta and approximation of the two vessels is obtained and maintained by

pressure taken in the arm This does not mean that no blood reaches the lower extremities but that it reaches them through such circuitous pathways that the force of the beat is lost There may be a difference in the strength of the pulse in the two radial arteries and this is often an indication that the left subclavian artery is implicated in the process—a point of some importance in considering the operative interference *Hypertension in the upper extremities is common* The systolic pressure may be above 200 mm. of mercury and the diastolic more than 100 The hypertension is probably due to the partial renal ischaemia which results from the slowing of the circulation and the diminished blood supply to the kidneys

Symptoms

The symptoms are usually minimal They are directly related to the constriction of the aorta and fall into two groups, one due to the hypertension in the upper extremities, and the second due to the sluggish circulation in the lower limbs. Headaches and throbbing in the head are often troublesome and there may be flushing of the face and a burning of the face and hands The hot feeling in the head and neck may be more marked on stooping Numbness and coldness of the lower extremities are not uncommon and some complain of weakness in the legs A frequent important diagnostic sign is the difficulty in the healing of wounds in the lower extremities, presumably from the poor circulation.

Cardiac Findings

On examination of the heart no increase in its size is usually found. Owing to the dilatation of the ascending aorta there may be visible pulsation in the episternal notch There is usually good clinical evidence of the collateral circulation producing pulsation in unusual places There may be pulsation in the supraclavicular fossa, in the interscapular region along the margins of the scapula, and in the axilla Murmurs are heard over any of the vessels of the collateral circulation and not infrequently it is the occurrence of a murmur in the interscapular region which suggests the possibility of a coarctation of the aorta In some cases the murmur is audible anteriorly over the internal mammary artery

X ray Examination

On x ray examination the ascending aorta may be dilated and visible to the right of the sternum Owing to the enlargement of the vessels which are given off the arch the top of the aorta appears to extend abnormally high in the apex of the chest It is difficult to visualise the descending aorta Notching of the ribs is seen in the x rays as the most characteristic single feature and is due of course to the erosion of the lower margins of the ribs by the very marked dilatation and pulsation of the intercostal arteries

Several workers have been able to demonstrate the constriction of the aorta by a radiogram after the injection of 70 per cent diodrast or other opaque medium.

Diagnosis

The diagnosis is based on the strong pulse in the upper extremities combined with a weak or absent pulse in the lower extremities. It is confirmed by the evidence of a collateral circulation such as murmurs in the interscapular region abnormal pulsation in the back or notching of the ribs

COMPLICATIONS

The most serious complications are those directly referable to the high blood pressure in the head and upper extremities. Cerebral accidents are common. Rupture of the aorta has been noted, usually proximal to the obstruction but also reported below the constriction. Aneurysmal dilatation of the descending aorta has been noted in these cases. Cardiac failure has been described and Hamilton and Abbot stated that 74 per cent of the patients died of cardiac failure before the age of 40. On the other hand Lewis, on the basis of extensive clinical experience, has emphasised that the condition is compatible with a long and active life. The vascular abnormality may be the seat of a superimposed infection especially with the organism *Streptococcus viridans*.

SURGICAL TREATMENT

Although coarctation has for long been considered a rare anomaly of the aorta for which little could be done, that outlook has now been changed. This is the result of the valuable experimental studies on dogs done in the first place by Crafoord and Nylin of Stockholm, and also by Gross and Hufnagel of Boston. It was demonstrated that the flow of blood to all the organs could remain suspended for as long as twenty-five minutes without there being any subsequent signs of organic damage, provided an adequate flow to the brain was ensured. Crafoord, on the strength of this observation, in certain patients with a patent ductus took the risk of placing clamp forceps on the aorta above and below the point of entry of the ductus into the aorta and of keeping them attached while the ductus was divided and the two ends sutured. In one of these cases the operation took no less than twenty-seven minutes without any noticeable post-operative disturbance. It was during this operation that Crafoord began to wonder whether it might not also be possible to treat coarctation of the aorta by surgical means. It was obvious that in a coarctation with such a satisfactorily functioning collateral system between the large arteries arising proximal to the coarctation and the arteries on the lower half of the body, he could venture to keep the aorta closed at a point immediately distal to the left subclavian artery for a very considerable period and certainly for much longer than twenty-seven minutes. The relatively bad prognosis in cases of aortic coarctation seemed to be sufficient justification for making an attempt at surgical treatment in these patients. The one point that he was anxious about was the fact that advanced changes of an arteriosclerotic nature had been demonstrated in the aorta and the great vessels arising from it. These changes, however, are a result of the heavy strain on the arterial wall caused by the constriction, and therefore if operation can be undertaken at a sufficiently early age they will probably not be encountered.

Selection of Cases

The indications for surgical treatment of this obstructive condition of the aorta are not yet quite clear but it is agreed by everyone that the best time for operation is before the age of 14 years, as at an early age the narrowness of the vessel prevents satisfactory suture and it is not yet known whether, when it is sutured, it will expand with the growth in size of the individual. In the later age groups there is likely to be some arteriosclerotic damage to the vessel walls or a so-called jet lesion, the result of damage to the opposite wall by the high-pressure stream of

good size The excised stenosis has often an opening little more than 1 to 2 mm. in calibre Anastomosis is carried out with an arterial suture using 5-O silk (Deknatel), starting at the medial aspect of the aorta with the knot on the outside Thereafter

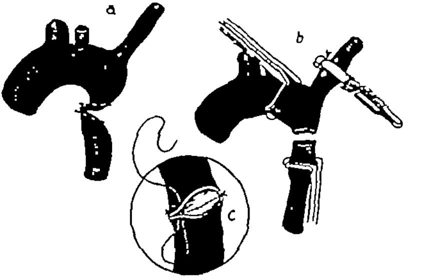

Fig 87 This illustrates one method of placing the lamps and the stitching

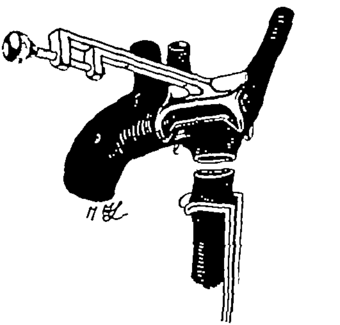

Fig 88 The use of Potts clamp in the operation for coarctation. The blood flow through the subclavian is obstructed in this method.

a running suture is placed along the posterior aspect in much the same way as in Potts operation for pulmonic tenosis—an easier method than the usual type of Carrell invaginating suture that is used by Gross Blalock and Crafoord When

the posterior line of sutures is put in it is knotted to a stay suture on its lateral aspect and then continued back to the starting point

Removal of the Clamps Before the clamps are removed half a pint of blood is run in rapidly and the head end of the table is lowered Firm pressure is applied to the anastomosis by means of a swab for the purpose of supporting the suture line when the vessel dilates on removal of the clamps The distal clamp is then removed slowly over a period of some minutes The other clamps are taken off equally slowly and the swab held against the suture line for about *one minute* before complete release

The rapid infusion and lowering of the head of the table is done because in Gross s first case the child promptly died on removal of the clamps This may have been due to cardiac dilatation after the sudden release of the previous obstruction with insufficient blood returning to it This catastrophe he prevents now by the procedures just described

Post-operative Treatment

Post-operative treatment is similar to that in pulmonic stenosis with one notable difference There is a great danger when aspirating the chest afterwards of damaging a large intercostal artery and causing serious or even uncontrollable haemorrhage It is probably wise to leave a very small catheter in the chest and clip it opening it up and aspirating through it if necessary It may be removed in forty-eight hours

Results of Operation

Probably slightly over 10 per cent of cases in which operation is begun prove to be inoperable The operative mortality is difficult to assess One recent speaker had 3 deaths in 10 operations but Crafoord s mortality is much less than that The figure will depend to a great extent on the age of the patient—being most satisfactory in the early years of the second decade—on the local conditions found and on the experience of the operator

CHAPTER 6

Thymectomy for Myasthenia Gravis

GEOFFREY KEYNES

HISTORY

THE SURGERY of the thymus gland has gone through several stages during the last forty years but it is only since 1941 that it has been intensively studied and that thymectomy has been recognised as one of the more standardized procedures in operative surgery

A few sporadic attempts to remove thymic tumours had been made in 1912 by Sauerbruch and in 1917 by von Haberer though without success Failure was inevitable as long as it was thought feasible to remove the thymus gland or even any particular part of it by a suprasternal approach The suprasternal removal of the thymus gland from children thought to be suffering from thymic asthma had also been practised in France by Victor Veau from 1910 and for several years he claimed substantial success for this operation. In due course however both the disease and the operation for its cure silently faded out, and at the present time thymectomy is seldom undertaken in any condition other than myasthenia gravis

The occasional association of myasthenia gravis with epithelial tumours of the thymus has long been recognised, though it was not until 1936 that such a tumour was successfully removed with resulting cure of the myasthenia gravis This was accomplished by Blalock at Baltimore and the further advance of thymic surgery was also initiated by him when he first removed an apparently normal gland from a myasthenic patient in 1941 Blalock reported on six thymectomies at the end of the same year and from this time thymectomy began to be practised regularly in this country and, to a lesser extent in America

Although Blalock early experiences with the operation were encouraging he lost interest in it or passed on to other fields of surgery and up to the present time has performed it only about thirty-five times Considerable series of thymectomies have been done also at the Massachusetts General Hospital in Boston and at the Mayo Clinic Rochester Minnesota and perhaps elsewhere The present writer

has performed the majority (numbering 140 up to January 1949) of the operations done in this country up to the present time at New End Hospital Hampstead and St Bartholomew's Hospital though several other surgeons have followed suit elsewhere

The advantage of the transsternal approach had been demonstrated by Blalock at the outset and there has never been any reason to use any other route The only change that has been made is in the extent of the exposure In the earlier operations the sternum was divided as far as the fifth costal cartilage Afterwards this seemed to be an unnecessary interference with the integrity of the thoracic box and the division was taken only as far as the fourth cartilage At the present time as described below the sternum is often split only to the third cartilage and these modifications of the technique have been accompanied by a progressive decrease in the operative mortality

CHOICE OF PATIENT FOR OPERATION

There are few patients with myasthenia gravis who should not be given the chance of recovery by losing their thymus glands The disease is found at all times of life from infancy to old age and it is only those past the fifth decade for whom the benefit is so problematical as to be sometimes hardly worth putting to the test Clearly operation should also be withheld when the patient is already so ill with myasthenia, and occasionally with other serious accompaniments that there can only be one result Almost every patient with myasthenia is so unhappy that he will be eager to face the risk of failure or even death in order to obtain relief but the surgeon must not allow this to override his judgment Too ready compliance will only serve to discredit an operation which can often claim brilliant results if properly applied The selection of patients is referred to again in the section dealing with results

GENERAL PRINCIPLES OF THE OPERATION

It is assumed that the thymus gland is producing an abnormal internal secretion which is responsible for the interference with the normal neuro-muscular mechanism The result of this interference is the condition known as myasthenia gravis If this assumption is correct the logical treatment is by surgical removal of the thymus gland and this removal can be total without any side-effect upon the patient's internal economy since the gland has no normal function that is known No patient has yet shown any sign of a metabolic deficiency after total extirpation of the gland

At the same time the myasthenic patient is very different from any patient, however ill who is not suffering from myasthenia gravis The myasthenic patient is the victim of a muscular asthenia which may be localised or generalised The weakness in its milder forms may be almost restricted to the bulbar area, the ocular orbicular facial and pharyngeal muscles being mainly affected In other patients it may be particularly the respiratory and accessory respiratory muscles that are weak In yet others the skeletal muscles in general may be affected together with one or both of the groups already mentioned The manifestations of the disease are indeed, almost infinitely variable but every patient is liable to show the same reaction to any surgical interference namely a temporary worsening of all the symptoms even with great weakness of muscle groups that were not obviously affected before

Each patient must therefore be approached as one who may develop a grave weakness of the respiratory mechanism immediately after the operation, and consequently every effort should be made to maintain the integrity of this mechanism This is done partly by therapeutic measures both before and after operation designed to maintain the physiology of the neuro-muscular apparatus as nearly normal as possible and partly by avoiding everything that may tend to impair the mechanical efficiency of respiration Every myasthenic patient has a narrow margin of respiratory safety compared with non-myasthenic patients and the operation for removal of the thymus gland must be planned accordingly

The first requirement, therefore is to plan the operation so that there is the least possible injury to the integrity of the thoracic box and avoidance if possible of even a temporary collapse of the lung

Myasthenic patients are also peculiarly susceptible to any acute bacterial infection, the muscular weakness becoming thereby gravely accentuated Post-operative pulmonary infection is, therefore, greatly to be feared

Some of these considerations will be fully dealt with in describing the pre and post-operative care of the patient. The mechanical factors only will be considered now

A thoracic surgeon accustomed as he is to a transpleural approach to the lung and the mediastinum might suppose that the thymus gland should also be reached by that route It should be the surgeon s first care however in operating on a myasthenic patient to avoid any method of approach that entails even the temporary collapse of a lung The pleura should not be opened except in circumstances of absolute necessity and these should never arise except during the attempted removal of a thymic tumour It may then be unavoidable The most suitable line of approach to the thymus gland in a myasthenic patient is therefore transternal since it is only by this route that injury to the pleura can be wholly avoided Division of the sternum in the midline gives moreover the ideal exposure of the thymus gland since it is a more or less symmetrical and centrally placed organ

The only question that may be debated is how far the division of the sternum should be carried to make complete extirpation of the thymus gland relatively simple Some surgeons notably those working at the Mayo Clinic in Rochester Minnesota, have advocated complete division of the sternum from the suprasternal notch to the cartilage of the xiphisternum Other surgeons have taken the view that this is an unnecessary interference with the respiratory mechanism, and have limited their division to the level of the third intercostal space In my own series of operations the level of the third space was used as a routine for several years More recently it has seemed that the level might be varied according to the length of the patient s chest a measurement which itself varies within wide limits. For the longer chests a division to the level of the third interspace is advisable; the lower end of the thymus gland may otherwise be very difficult to reach For the short chests which are seen particularly in women division to the level of the second space is quite adequate and presumably impairs the efficiency of chest expansion and coughing less than the longer division Judgment must, therefore be exercised and the operation, like most others should not be performed by rule of thumb

Apart from these considerations the operation must be planned so that it shall take no longer than is necessary At the same time there ought to be no sense of

hurry since any undue urgency may result in injury to the pleura which should almost always be left intact Experience has shown that while the operation may sometimes be completed within fifty minutes it may sometimes require seventy minutes The average time taken is approximately one hour There should be no unnecessary elaboration of technique and no superfluous movements Surgeon assistant anaesthetist and nursing staff should form a trained team and it is only by this means and by careful attention to every detail of the operation that the best results will be obtained

CARE OF THE PATIENT BEFORE OPERATION

Determination of the Optimal Dosage of Neostigmine (Prostigmine)

The main object of treatment before thymectomy is to ascertain, once the diagnosis has been fully established what dosage of neostigmine is needed to maintain the patient's muscles at their best efficiency It is often found that patients before admission to hospital have been encouraged to keep the neostigmine at as low a level as possible This attitude may be partly a measure of economy but partly it is founded on a belief that it is deleterious to give the drug in larger quantities than is absolutely necessary There does not seem to be any good reason for this belief and we have found that patients always benefit by increasing the dose or its frequency or both to the maximum that can be tolerated Sometimes the effect of neostigmine is increased by the simultaneous administration of ephedrine When the neostigmine has reached the highest level that can be tolerated the spill-over from the voluntary neuro-muscular system to the sympathetic system is usually shown first by intestinal colic, sometimes with diarrhoea. The dose must then be reduced to a level at which the colic no longer occurs Atropine given at the same time may help to achieve this

When the patient is first admitted to the hospital it is advisable to plan a period of from twelve to twenty four hours during which no neostigmine is given though this must not, of course, be prolonged to a point at which there is danger to the patient's life from respiratory failure Usually twelve hours abstention is enough to show the full degree to which the untreated myasthenia affects the patient A full examination is then done and records made by which any improvement that takes place after operation can be measured The signs that are of the most value for this purpose are as follows:

1. The degree of ptosis and the strength of the orbicularis oculi when contracted as much as possible
2. The movements of each eyeball.
3. The efficiency of the facial muscles as shown by attempts to smile to expose the teeth, and to whistle
4. The efficiency of the masseters in keeping the lower jaw clenched against resistance
5. The strength of the neck muscles
6. The length of time for which the patient can continue to read aloud so as to be intelligible Often the voice and ability to articulate die away in a few minutes
7. The ability to produce an explosive cough

8 The strength of the trunk muscles as tested by directing the patient to sit up from a fully recumbent position with the arms folded across the chest.
9 The strength of the deltoid muscles by testing the patient's ability to lift the arms away from the body against the pressure of the observer's hand
10 The ability to extend the fingers when the fist is first clenched and dorsiflexed. If the fingers can be extended, the strength of attempts to maintain the position against pressure can be tested
11 The ability to raise the straight leg from the bed when in full recumbency
12 The ability to dorsiflex the foot against resistance

There are many other clinical tests that can be applied, but these twelve are usually enough. When they have been noted, the patient is given an injection of 2 mg. (1/32 grain) of neostigmine and the tests are made again after ten or fifteen minutes. *A good idea has then been formed of the full degree of myasthenia from which the patient is suffering and of the degree of the response to neostigmine.* From the post-operative point of view No. 7 above, relating to the cough, is the most important test of all, since on this depends the patient's ability to keep the smaller bronchi free from plugs of mucus and so to avoid a pulmonary atelectasis.

It is usually found that neostigmine tablets given by the mouth at two-, three-, or four-hour intervals are quite adequate to keep the patient at a comparatively high level of efficiency. Sometimes occasional injections are needed in addition.

It serves no purpose to state an "average dose" of neostigmine that is needed since every patient must be studied individually. For the milder degrees of myasthenia 75 mg. (1 1/4 grains) during the twenty-four hours may be enough. Other patients may need up to 200, 300, or even 400 mg. (3, 4 1/2 or 6 grains) before their needs are satisfied. It is usually advisable to have the patient under observation for at least a week while being "built up" to the proper neostigmine dosage. If the patient is undernourished because of dysphagia from weakness of the palate and fauces *a much longer time may be needed for pre-operative care.*

Miscellaneous Measures

For several days before operation the patient is drilled by the nurse-in-charge in fully expanding the chest by slow inspiration and expiration, and in coughing to order.

The nursing staff must be warned never to administer an enema to a patient suffering from myasthenia gravis. An alarming syncope is often found to follow this, the explanation of which is unknown.

Immediate Pre-operative Measures

On the day of operation the neostigmine doses are so timed that one is given thirty minutes before the operation. This consists of an injection of 1 mg. (1/64 grain) or occasionally 2 mg. (1/32 grain) of neostigmine with 0.9 mg. (1/[illegible] grain) of atropine sulphate. For medication before the anaesthetic omnopon 20 mg. (1/3 grain) and scopolamine 0.4 mg. (1/150 grain) are given one hour beforehand. It should be a matter of routine to give an injection of neostigmine 1 mg. and atropine 0.6 mg. (1/100 grain) while the wound is being sutured, that is, ten minutes before the patient leaves the operating theatre. The anaesthesia is usually light and the patient should be able to cough within a short time of the end of the operation.

X RAY EXAMINATION

An extremely important part of the pre-operative care of the patient is the preliminary examination by x ray The chief object of this is to detect if possible all thymic tumours so that these may be treated by deep x ray therapy before operation is undertaken The normal thymus can sometimes be demonstrated in an infant on an x ray film because of the relatively large size of the gland In older people it is relatively much smaller and can never be shown Thymic tumours which occur in 10 per cent of myasthenic patients coming for treatment are on the other hand relatively opaque since they consist of dense epithelial masses usually with a thick fibrous capsule The majority are formed in the lower part of the gland and so lie on the first part of the aorta and the pericardium If they are large they may project laterally far enough to be seen in the antero-posterior view of the mediastinum Usually they are best seen in an accurate lateral view lying on the aorta and pericardium Most radiologists are unfamiliar with the appearance of these tumours owing to their rarity—so that the surgeon should not accept a negative report until he has himself verified it on the films Tomography may be a useful adjunct to ordinary radiology in detecting and locating tumours of the thymus

The reason for exercising great care in looking for tumours is as follows Experience has shown that the results of a primary operation for these tumours are extremely bad as described in the section on *Results* Better results appear to be obtained if operation is postponed until the patient has been given a course of deep x ray therapy This can be done with great accuracy when the tumour has been demonstrated by radiography so that injury to the lungs can be avoided The operation is not made more difficult by radiotherapy but may even be made easier since the tumour is usually found to be smaller than before and the pleura becomes less rather than more adherent

THE OPERATION OF THYMECTOMY

Position of the Patient

The patient lies flat on the back with the head extended (Fig 89) It is an advantage if the Dunhill thyroid bridge is available on the operating table so that the shoulders may be raised and the thorax brought forward If the bridge is not available a wedge-shaped pillow or a sandbag is placed beneath the shoulders so as to produce the same effect.

The sternal part of the chest tends to be flat in men In women it is often sloped forwards at a considerable angle It may be advantageous to tilt the operating table with the feet downwards according to the degree of slope of the chest, so making it more level for the operator

The points of the shoulders should be free so that they can be displaced backwards slightly when the two halves of the sternum are spread at a later stage of the operation

The operator stands on the right hand side

The Anaesthetic

The anaesthetic must be so administered that the lungs are fully controlled throughout the operation and so that all factors tending to produce irritation of the

respiratory system are avoided Ether must therefore not be used, and it is not necessary to introduce an intratracheal tube An efficient airway and a well fitting mask kept in position by a rubber harness will provide the necessary conditions for the successful use of non-irritant anaesthetic gases

Premedication is effected by an injection of omnopon 20 mg ($1/3$ grain) and scopolamine 0 4 mg ($1/150$ grain) half an hour before the operation is timed to begin.

Anaesthesia is induced by intravenous pentothal and is continued by oxygen and cyclopropane *Movement of the lungs is thereby largely avoided and the operation* made much easier for the surgeon Exhaustion of the patient and loss of heat are also avoided and there is usually no appreciable raising of the pulse rate or signs of surgical shock during the operation

The patient should show signs of returning consciousness within ten or fifteen minutes of the end of the operation

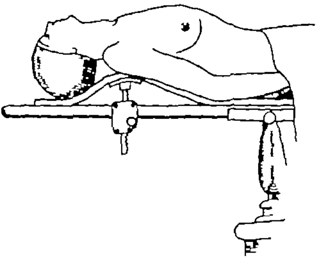

Fig 69 The position of the patient on the operating table for thyroidectomy

An intravenous drip of blood or saline during the operation or afterwards is not only unnecessary but is positively harmful

Infiltration of the Skin

It is advantageous to infiltrate the subcutaneous and deeper tissues with a weak solution of adrenaline in normal saline (1 250 000) *in order to minimize bleeding* from small vessels The infiltration is made over an area 4 inches wide at the root of the neck above the sternal notch and in the midline from the sternal notch to the level of the second or third intercostal space This is carried down to the periosteum of the sternum

The infiltration may also be extended in the second or third interspace on either side according to whichever space has been chosen as the level for division of the sternum

A total volume of 250 to 300 of adrenaline solution may be needed

The Skin Incision (Fig. 90)

A horizontal* incision 3 to 4 inches long is made just above the suprasternal notch (Fig. 90). This divides the skin and platysma muscle and exposes the sternal insertions of the sterno-mastoid muscles. Subcutaneous vessels are seized and tied. The finest catgut (OOOO) is used so as to avoid formation of subcutaneous blebs of serum along the suture line after healing has taken place.

A vertical midline incision is now carried down from the middle of the horizontal incision to the level of the middle of the 3rd or the 4th rib according to whether the 2nd or 3rd space has been chosen for division of the sternum. This incision is carried down to the bone dividing the periosteum. Usually there are one or two vessels in the periosteum which give rise to considerable bleeding but it may be difficult to seize these with artery forceps. They may be successfully underrun with a needle and catgut and so tied.

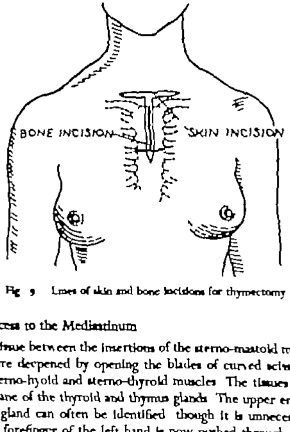

Fig. 9. Lines of skin and bone incisions for thymectomy

The Upper Access to the Mediastinum

Connective tissue between the insertions of the sterno-mastoid muscles is incised and the exposure deepened by opening the blades of curved scissors between the edges of the sterno-hyoid and sterno-thyroid muscles. The tissues are thus opened down to the plane of the thyroid and thymus glands. The upper ends of the cornua of the thymus gland can often be identified though it is unnecessary to do so at this stage. The forefinger of the left hand is now pushed through the opening that has been made into the upper part of the anterior mediastinum as far as it will

* The incision originally described by Blalock (1 94) was along a single vertical line in the midline of the neck, straight down to the level of the division of the sternum. The T incision has been used in all operations for thymectomy done by me since experience in thyroid surgery had shown long before that a collar incision gives a much better scar in the neck than any vertical incision. The horizontal limb of the T gives plenty of freedom of skin-flaps during the spreading of the sternum. No undermining of the skin is necessary.

reach The finger forcibly separates from the back of the sternum any attachments of muscle or connective tissue that are encountered

Occasionally it may be possible at this stage to diagnose by touch a *thymic tumour* which has been missed in the x ray films Any such tumour will feel craggy and irregular If a tumour can be diagnosed thus with confidence it will usually be best to abandon the operation for the time being in favour of deep x-ray therapy The skin incision is then closed

Assuming that no tumour can be felt the next step is to divide the ligament crossing the suprasternal notch with a knife Usually there is also a blood vessel crossing the space just in front of the ligament and it is a wise precaution to seize this on either side with artery forceps before it is divided as it may be difficult afterwards to pick up the ends This vessel is thus divided at the same time as the ligament and is tied after under running with a small half-circle needle

The Lower Access to the Mediastinum

The 2nd or 3rd intercostal space whichever has been chosen is now identified on either side An incision is made across the periosteum of the sternum, and through the muscle at the level of the lower border of the 2nd (or the 3rd) rib for about 1 inch beyond each side of the sternum A flap of muscle and periosteum is then raised on each side with a rugine until the edges of the sternum are reached and the spaces exposed The blade of the rugine is then carefully inserted just under the edge of the sternum in the space great care being taken not to let the instrument slip suddenly deep into the mediastinum If this does happen the pleura may be injured During the exposure of the space there is often free bleeding from a perforating branch of the internal mammary artery This must be controlled by pressure with gauze as it is usually not possible to tie it at this stage

The forefinger of the left hand is now again inserted into the mediastinum from above and at the same time a slightly curved blunt dissector is carefully inserted into each space below in turn The point of the instrument and the finger should be made to meet on either side behind the sternum and these together push the pleura sideways to right and left so that it may escape injury during division of the sternum.

Bleeding from the mediastinal tissues during these manoeuvres is variable It is sometimes free for a short time but is never serious

Division of the Sternum (Fig 90)

If a *Lebsche chisel* and a hea y mallet (Fig 91) are available the sternum is now divided horizontally from one intercostal pace to the other A cleaner cut is obtained if the bone is ut half way across from each side

Some operators use the same form of chisel for di iding the whole length of the sternum from one intercostal space up to the suprasternal notch as in the diagram This is not too difficult if the bone is soft but in an adult male it may be a tedious process and need con iderabl iolence In my hands it has been much quicker and less shocking to the patient to use a *Sauerbruch sternum splitter* (Fig 92) The lower flat blade of this instrument i inserted through the upper opening into the mediastinum and the ternum then di ided lown the middle by a series of cut until the transverse cut is reached The assistant will make it possible to introduce the haft of the instrument between the two hal es of the sternum after the first cut by

dragging them apart as much as is possible with a small retractor on either side. When the transverse cut is reached the sternum splitter is removed and the division of the periosteum on the back of the sternum at this level is completed with a strong pair of scissors.

If the Lebsche's chisel was not used the transverse cut is made *after* the vertical cut has been completed by introducing the lower blade of a Doyen's rib shears through each intercostal space in turn and cutting the bone to the midline to meet the vertical cut.

The two halves of the upper part of the sternum should now be free and they should be pulled apart with small retractors so that the cut edges may be examined.

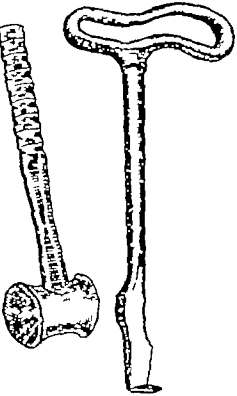

Fig. 9. Lebsche chisel and mallet

These cut edges are the main source of blood loss *throughout* the operation and any bleeding that can be seen should be stopped at this stage by pressing small lumps of *Horsley's* wax into the cancellous bone. When the bleeding has in this way been controlled the connective tissue and pleural membranes are swept back on either side by pressure with moist gauze. A strong self retaining retractor is then inserted and the halves of the sternum held apart so that an opening 3 inches wide into the anterior mediastinum can be maintained.

Exposure of the Thymus Gland

When the mediastinum is first opened nothing can be seen except connective tissue, most of the fibres of which appear to run transversely, coloured with effused

reach. The finger forcibly separates from the back of the sternum any attachments of muscle or connective tissue that are encountered.

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Division of the Sternum (Fig. 90)

If a *Lebsche chisel* and a heavy mallet (Fig 91) are available the sternum is now divided horizontally from one intercostal space to the other A cleaner cut is obtained if the bone is cut half way across from each side

Some operators use the same form of chisel for dividing the whole length of the sternum from one intercostal space up to the suprasternal notch as in the diagram. This is not too difficult if the bone is soft but in an adult male, it may be a tedious process and need considerable violence In my hands it has been much quicker and less shocking to the patient to use a *Sauerbruch's sternum splitter* (Fig 92) The lower flat blade of this instrument is inserted through the upper opening into the mediastinum and the sternum is then divided down the middle by a series of cuts until the transverse cut is reached The assistant will make it possible to introduce the haft of the instrument between the two halves of the sternum after the first cut by

dragging them apart as much as is possible with a small retractor on either side. When the transverse cut is reached the sternum splitter is removed and the division of the periosteum on the back of the sternum at this level is completed with a strong pair of scissors.

If the Lebsche chisel was not used the transverse cut is made *after* the vertical cut has been completed by introducing the lower blade of a Doyen's rib shears through each intercostal space in turn and cutting the bone to the midline to meet the vertical cut.

The two halves of the upper part of the sternum should now be free and they should be pulled apart with small retractors so that the cut edges may be examined.

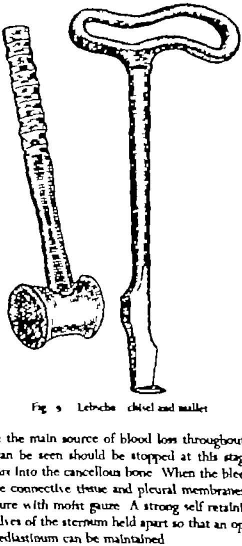

Fig. 5. Lebsche chisel and mallet

These cut edges are the main source of blood loss throughout the operation and any bleeding that can be seen should be stopped at this stage by pressing small lumps of *Horsley's* wax into the cancellous bone. When the bleeding has in this way been controlled the connective tissue and pleural membranes are swept back on either side by pressure with moist gauze. A strong self retaining retractor is then inserted, and the halves of the sternum held apart so that an opening 3 inches wide into the anterior mediastinum can be maintained.

Exposure of the Thymus Gland

When the mediastinum is first opened nothing can be seen except connective tissue most of which the fibres of which appear to run transversely coloured with effused

blood (Fig 93) These fibres are then picked up and divided exactly in the midline for the whole length of the exposure The pleural membranes will then tend to fall apart to either side and escape injury Soon the yellowish-pink smooth surface of the thymus gland will appear in the incision, and all cutting instruments are then laid aside Two pairs of toothless dissecting forceps, preferably with wide flat blades, are taken up and the gland is exposed by blunt dissection, the pleural membranes being peeled off each lobe of the thymus gland in turn and pushed to either side (Fig 94) The fold of pleura which covers each lobe to a variable extent can usually be seen and, if care be taken, can be peeled and then pushed aside without injury The lateral border of each lobe of the gland is reached by this proc

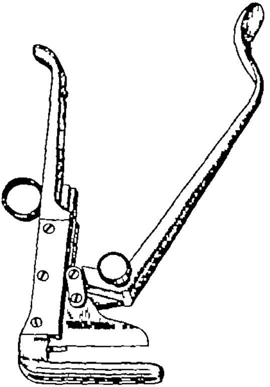

Fig 92 Sauerbruch sternum splitter

ess and although it may be more or less continuous with mediastinal fat on either side of the aorta the limits of the gland can usually be determined. The fat is friable and breaks away as soon as the firmer glandular substance has all been separated from the pleura. The mottled surface of the lungs can usually be discerned through the transparent pleura at some stage of this process, and the operator can satisfy himself that both lung and pleura are intact.

At this point the operator can usually introduce a finger under the edge of one or the other lobe of the gland and can strip it from the surface of the aorta up to the innominate vein and down to the pericardium.

There are no vascular connections with the aorta, but usually during the process of stripping the pleural membrane one or more blood vessels will have been en-

countered These are always surprisingly small the largest usually being a vessel to the lateral borders of the thymus near the top passing obliquely downwards and inwards from the direction of the thyroid axis or inferior thyroid arteries Any strand of tissue that looks as if it might be a blood vessel is divided between artery forceps and tied with fine catgut so that there should be no arterial bleeding Each vessel is tied as it is encountered, so that there is no accumulation of instruments in the operation field Six inch artery forceps (Dunhill s pattern as made by Down Brothers are the best) should be used as the ordinary forceps will at this stage be too short for convenience

The lateral borders and posterior surface of the body of the gland are now free from their surroundings, and the shape of the whole gland should be discernible

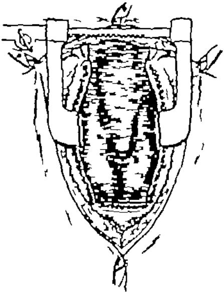

Fig 93

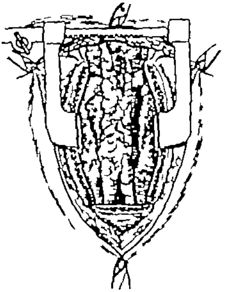

Fig 94.

Fig 93 Drawing to show the appearance of the mediastinum when just opened by splitting the sternum The connective tissue is incised in the midline t expose the thymus gland.

Fig 94. Drawing to show the relationship of the thymus gland to the rough bony structures when the gland has been fully exposed. (Behind left innominate ein aorta pericardium. T either side—lungs and pleura)

Attention is now turned to the cornua of the gland on each side in turn. These are variable in their length but both usually extend up into the neck and almost, or quite meet the lower border of the isthmus of the thyroid gland Each cornu is seized and separated by blunt dissection care being taken to avoid injury to the inferior thyroid veins which lie just behind them

Each cornu is accompanied by a blood vessel. It is clamped as high up as possible di ided and securely ligated

The cornua can now be turned downwards so that the posterior surface of the upper part of each lobe can be separated from the surface of the left innominate vein Any abnormality of position will probably ha e been noticed already but it must be borne in mind that about once in forty operations it will be found that one

or both lobes of the thymus gland lie behind the left innominate vein When the cornua are turned down this variation if present, will be obvious and the aberrant lobe must then be carefully separated from the back of the vein and pulled down from below Search must now be made for the venous drainage of the gland Normally a vein drains from the posterior surface of each lobe and these usually unite to form a single large trunk half an inch or less in length which drains into the anterior surface or lower border of the innominate vein (Fig 95) sometimes the vein from each lobe enters the innominate separately This must be divided between artery forceps and securely tied close to the innominate vein, but with a pedicle long enough for safety Bleeding would be very serious if this ligature slipped or came undone and there would also be a risk of fatal air embolus during inspiration

Fig 95 Diagram of a thymus gland with the upper cornua turned down to show the venous drainage into the left innominate vein.

When the large vein (or veins) has been cut and tied the whole gland can be turned further downwards and its lateral connections, if any remain, divided. It is then attached only to the pericardium This attachment is usually hidden by the pleural membranes below their point of fusion behind the lower part of the sternum The gland must therefore be pulled up and stripped from the pericardium There are no vascular connections below but it may be wise to clamp and cut the remaining tissue lest the pericardium or pleura has been unwittingly dragged up and so may be in danger of injury The gland is now completely detached and can be removed (Fig 96)

It has been assumed throughout the description that the pleura has escaped injury If by any mischance or false move it has been holed the sucking of air into the pleural cavity will be heard The anaesthetist is immediately warned of this so that he may prevent collapse of the lung on the affected side The rim of a small hole can usually be seized in artery forceps and ligated If the tear is too large for this

it can sometimes be sutured with a small needle and fine catgut but this is notoriously difficult to achieve because the mediastinal pleura is extremely thin

During the process of dissection of the thymus gland the mediastinum should be kept clear of blood and blood-clot by gentle mopping with wet swabs of gauze which have all been counted by the nursing staff When the thymus gland has been removed the cavity in which the lungs pericardium aorta and innominate vein can be clearly seen is quickly mopped out and inspected for bleeding points If it appears to be reasonably dry the self retaining retractor is removed and the two halves of the sternum allowed to spring together again

Closure of the Mediastinum

The two halves of the sternum have been strained upwards and outwards during the removal of the thymus gland which may have taken thirty or forty minutes

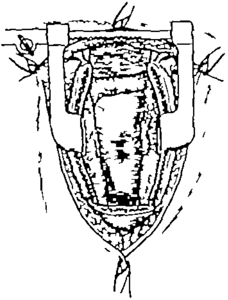

Fig. 56. Drawing to show the mediastinum after removal of the thymus gland

They will not come accurately together again when the retractor is removed but will remain partly elevated with a gap of half an inch between the edges The anaesthetist or assistants on either side then place closed fists beneath the shoulders so that they are pushed forwards and the bridge is lowered, or the pillow pulled up The sternal gap then closes accurately and the overlying tissues (*muscle and periosteum*) are united with interrupted sutures of strong catgut It seems to be unnecessary to spend time fixing the bone edges together with metal wire as the amount of movement after the catgut suturing is small and the sternal edges become glued together in three or four days

When the suturing of the sternal periosteum is complete the anaesthetist inflates the lungs to expel any blood that may have accumulated in the mediastinum and this is removed with swabs or an aspirator while the edges of the opening in the soft tissues above the sternal notch are sutured with finer catgut

The mediastinum is not drained and the closure should be air tight

The operation has now been almost completed and at this point an intramuscular injection of 1 mg (1/64 grain) of neostigmine should be given so that respiration and coughing shall be fully efficient as soon as the patient begins to regain consciousness

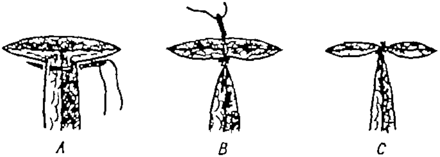

Fig 97 Diagram of the method of suturing the junction of horizontal and vertical limbs of the skin incision.

Closure of the Skin Incision

The subcutaneous fatty layer is next closed with interrupted sutures of fine catgut, some of the stitches being anchored to the underlying periosteum This helps to prevent the accumulation of serum between the skin and the sternum, which may if it occurs cause a breaking-down of part of the wound even a week or more after the operation

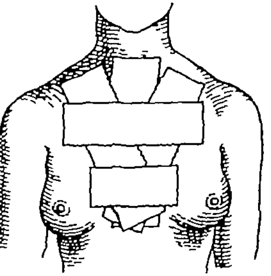

Fig 98 Diagram of the elastoplast dressing to be used after thymectomy

The edges of the platysma muscle are united along the whole length of the horizontal incision by interrupted sutures of fine catgut. The top corners of the vertical skin incision are now united by a horsehair or fine nylon suture The anaesthetist relaxes any tension there may be by flexing the head towards the chest and the middle of the upper skin flap is brought down accurately to the top of the

vertical incision by passing a second horsehair suture through the skin and round the first suture (Fig 97) This always gives accurate healing and a good scar

The remainder of the incision in the neck is accurately closed with horsehair sutures or clips

The vertical incision is closed with nylon sutures A few clips may sometimes be used if the skin is not too thick but healing is not so rapid over the chest as it is in the neck and nylon sutures will be more secure than clips It is very important that these should not be removed too soon

Dressing the Wound

The line of the incision is lightly powdered with sulphanilamide or sulphathiazole to maintain asepsis of the surface and several layers of gauze are applied No wool is used, the gauze being kept in position by strips of elastoplast applied for the most part longitudinally as in the diagram (Fig 98) so that there will be no interference after the operation with the expansion of the chest

The patient is then returned to bed

REMOVAL OF A THYMIC TUMOUR

The foregoing description of the operation of thymectomy has assumed that no thymic tumour is encountered The great majority of these should have been detected beforehand by radiography so that there should be few surprises If the removal of a thymic tumour is being undertaken with or without preliminary deep x ray therapy the level to which the sternum is divided must be planned so as to give a full exposure The level of the third interspace will usually be advisable since the tumours tend to be low down in the mediastinum The presence of a tumour can be detected with the finger as soon as the mediastinum is opened because it has an irregular surface and is usually very hard in consistency

The tumour is exposed in the ordinary way by incising the overlying connective tissue in the midline and an attempt is then made to peel the pleura off its surface The pleura covering the tumour is always much thickened but may be at the same time so adherent that it cannot be detached If it cannot be peeled off it must be deliberately opened and cut away with the tumour the lung meanwhile being kept distended by the anaesthetist An attempt to suture the pleura after removal may be made but usually it will fail and special care must be taken to distend the lung during the post-operative period as described later The tumour may also be densely adherent to the aorta and the pericardium usually it can be separated easily from the aorta though it may be necessary to excise a portion of the pericardium. Sometimes a tumour is found to extend laterally and to envelop the root of one lung It will then usually be inoperable or it may be possible to remove only a part of the tumour

Judgment must always be exercised as to how far it will be safe to go in the removal of a tumour If it has to be left behind its presence is almost certain to prove fatal in the long run On the other hand the risk to the patient is inevitably much increased by removal of a tumour especially if both pleurae have to be opened so that the immediate danger must be weighed against possible benefit. Abandonment of the operation on this score must sometimes be faced If the patient survives

the operation then his life may be prolonged by further deep x ray therapy so that the operator who is too ruthless may only be sacrificing the patient s true interests to surgical virtuosity

OPERATIVE MORTALITY

The myasthenic patient is for the reasons already given an unfavourable subject for any major operation Respiratory efficiency is often greatly impaired by the weakness of the respiratory muscles sometimes it is the diaphragm, sometimes the intercostal and accessory muscles that are particularly affected and the response of *these muscles to neostigmine is not always either rapid or complete The patients* are therefore particularly susceptible to pulmonary infections and this risk is greatly increased if there is any collapse even temporary of either lung The ineffectual cough resulting from muscular weakness makes it difficult for the patient to keep his respiratory tract free from plugs of mucus so that atelectasis is a complication to be feared In addition a myasthenic patient may have a respiratory crisis in which floods of frothy mucus are produced and cannot be expelled so that he is in danger of drowning in his own secretion. Also the patients are often debilitated from long confinement in bed or invalid chairs and sometimes are poorly nourished owing to their difficulty in chewing and swallowing their food. Finally myasthenia gravis is sometimes associated with thyrotoxicosis which may be severe.

With all these factors in the balance against the patient s welfare it would not be surprising if the mortality of thymectomy were high. Among the earlier patients of our series when experience was limited, the mortality was indeed high, and 7 operati e deaths occurred among the first 21 patients Of the next 30 patients however only 1 died and this low rate of mortality has been consistently maintained Clearly therefore it would be misleading to assess the operative mortality in comparatively experienced hands as a percentage of the whole series The truth is *better represented by stating the mortality seen in the last 100 operations, and* furthermore these 100 operations exclude those done upon patients with thymic tumours since these present a separate problem which has to be attacked in quite a different way The operati e mortality calculated in this way amounts at the present time to 4 in 100 It is only close attention to detail in operative technique, pre and post-operative care that can maintain the mortality at this low level

The Cause of Death

It is well known that patients with myasthenia gravis are liable to sudden attacks of respiratory embarrassment and that death during such an attack is a not infrequent event The attack begins with an increased secretion of frothy mucus and the patient has more and more difficulty in expelling it from the respiratory passages Cyanosis soon appears and may become rapidly worse until the patient dies in the course of a few hours During this myasthenic crisis neostigmine seems to lose its effect, and so there may be no means of helping the patient through his difficulties

Often after operation the myasthenic patient experiences minor symptoms of this kind, but they do not cause anxiety Rarely an acute crisis may begin to appear almost immediately after operation and one patient has died within three hours.

The more usual cause of death after thymectomy is broncho-pneumonia Various

contributory causes have already been summarized but it should be realised that a vicious circle may be set up which may even end in complete respiratory paralysis. Clinical observation of myasthenic patients soon leads to realization that myasthenia gravis like other endocrine disorders is made progressively worse by any acute infection. This becomes obvious even when the patient has nothing more serious than a common cold. It follows that broncho-pneumonia quickly leads to an increase in myasthenic symptoms and this in its turn to increased respiratory inefficiency. Death will therefore sometimes follow signs of broncho-pneumonia very rapidly, so rapidly indeed that the lung infection is only recognised at the autopsy.

Post-operative haemorrhage has not hitherto been a cause of death nor has wound infection, on the few occasions when it has occurred, led to any serious results.

In the earlier part of the series in which the post-operative mortality was high a serious problem was the excessive secretion of frothy mucus from the trachea and lungs. It had been recommended by Blalock in his original report that patients after thymectomy should be given an intravenous drip of normal saline. He also remarked they should be kept at first lying flat with the head at a lower level than the feet to assist drainage of mucus from the lungs; he even advocated the use of continuous suction from the pharynx to assist the patient's efforts to keep the respiratory passages clear of froth. Soon it became apparent that there was a direct connection between these two recommendations and abandonment of the intravenous therapy produced a striking reduction in the respiratory secretions. It is in fact clear that patients after thymectomy should not be given any extra fluid. The blood loss at operation is not, as a rule, excessive, and if the patient is kept dry the mucus secretion is usually reduced to a manageable quantity. All intravenous therapy is therefore to be avoided.

THE CARE OF THE PATIENT AFTER OPERATION

For at least a week after operation the patient should be kept if possible in a room by himself. No one should enter his room without wearing an impervious mask to reduce the risk of extraneous respiratory infections.

Reference has already been made to the desirability of keeping the anaesthesia light during the operation. A long post-operative period of unconsciousness with its attendant risk of accumulation of secretions in the respiratory passages is thus avoided. The pre-operative cough drill and forced respiration can be brought quickly into use and expectoration encouraged at hourly intervals except when the patient is asleep.

Administration of Neostigmine

Neostigmine should be given at first by intramuscular injection in doses of 1 or 2 mg. (1/64 to 1/32 grain) at three-hourly intervals in the average patient. It is usually possible to revert to giving the drug by mouth as before the operation within two days but no rules for dosage can be laid down. Individual needs must be studied, particularly the effect of the operation on the symptoms. Commonly these are at first worse than before and the neostigmine must be given in larger amounts to counteract this tendency. If the post-operative course is smooth, the dose may be gradually reduced until in two or three weeks it may reach the same level as before

operation There may be notable exceptions to this in either direction, as described in the section dealing with results

Pneumothorax or Haemothorax as Complication

Emphasis has already been laid on the importance of avoiding, if possible even a temporary collapse of a lung If the thymectomy has been accomplished, as it usually should be without any injury to the pleura, there will be no pneumothorax and no collapse Occasionally however pleural injury occurs without the surgeon s knowledge and consequently there may be an entirely unexpected pneumothorax or haemothorax or both These will always be present in varying degree when there has been an unavoidable opening of the pleura It is therefore advisable to have an x ray examination of the thorax made *as a routine* within twelve hours of the operation If a pneumothorax is then seen, or more than a small amount of fluid is present, steps should be taken at once to remove either or both by aspiration and this should be repeated as indicated by the results of radiography on successive days until it is clear that the lung is fully expanded. The x ray films will always show a widening of the mediastinal shadow owing to the temporary effusion of blood and serum into the large dead-space created by the operation but it is usually of no significance and the effusion is soon absorbed

Avoidance of Extra Fluids, Post-operative Shock

Reference was made in a previous section to the necessity for avoiding the administration of extra fluids to the patient after operation Intravenous therapy should never be used Post-operative shock is usually not severe and if all goes well there is no great change to be seen on the patient s chart in pulse rate temperature or respiration rate Occasionally the pulse rate may run at 130 or over for a few days for no obvious reason, but this need not give rise to anxiety

Pulmonary Infections

If there should be any pulmonary complications, they are apt not to show themsel es until three or four days after operation The fourth day is indeed, the danger period and when this is passed without rise in temperature or respiration rate it becomes progressively less probable that any trouble will arise Any undue degree of fever at any period must, of course be met immediately by penicillin in a dosage of not less than 40 000 units every four hours and physical signs in the chest must be watched Careful judgment must be exercised in giving either expectorants to loosen bronchial secretions or atropine to dry them up Either effect may easily be o erdone great increase in the olume of secretions or in their viscidity being undesirable

Measures to Promote Patient's Comfort and Well-Being

The position of the patient during the first few days after operation should be adjusted so as to gi the greatest possible comfort Absolute recumbency or lowering of the head to promote drainage of bronchial secretions with or without a suction tube in the pharynx should scarcely ever be necessary After the first few hours the patient should be loped on pillows so that the hourly exercise in deep

breathing and coughing is made easy Every patient will complain of some pain owing to movement between the cut edges of the sternum but this is usually slight with ordinary breathing Pain is often rather severe at first when the patient coughs and some persuasion may be necessary to make him do it This soon improves and it is not necessary to insist on the performance of the cough drill once it is clear that the course is set fair It is often of great assistance to the patient to place a hand firmly on each side of the chest while he is making his cough

Post-operative Diet

Vomiting after operation is uncommon and the feeding of the patient is regulated by his capacity for masticating his food and for swallowing it When the palatal muscles are very weak solid or semi-solid food will be swallowed better than fluids The greatest nutritive value that is compatible with the patient s limitations must be aimed at

Removal of Sutures, Serum Exudation

It will have been appreciated from the above remarks that the patient s post operative course will depend largely on the condition of the lungs If these remain free from complications there will be little cause for anxiety and convalescence will be rapid The stitches or clips in the horizontal limb of the incision can be removed in two days as in a thyroid operation except for the suture at the meeting point of horizontal and vertical limbs This and the sutures in the vertical part can be removed in the course of a week, but the skin over the sternum is thick and has been cut at right angles to the natural lines of cleavage so that it does not heal with more than average rapidity Sometimes, too a considerable amount of serum will tend to accumulate in the mediastinal dead-space and as this tends to be compressed by the expansion of the lungs, it sometimes percolates between the cut edges of the sternum and bulges forward the overlying skin

If this pressure from within is not relieved before the last skin sutures are removed a part of the incision may gape and if this happens the resulting gap will take a considerable time in healing As soon therefore as any bulging is noticed the serum should be removed by aspiration through a wide-bore needle and this should be repeated daily for as long as may be necessary

Getting Out of Bed

This exudation of serum may delay the patient s getting out of bed It is not often however that getting up can be allowed within ten or fourteen days of the operation Beyond this the patient s response to neostigmine is the usual limiting condition If the response is so good or improvement in symptoms is so rapid that general muscular tone is not far from normal with or sometimes even without neostigmine then there can be no reason for limiting the patient s activity At the same time it must be remembered that many myasthenic patients are so determined to show improvement that they may be overeager to exert themselves The medical attendant must satisfy himself of the patient s capacities by tests of the efficiency of various muscle groups particularly those of the lower limbs and trunk, before he instructs the nursing staff to encourage getting up and walking

The Psychology of Myasthenic Patients

It is appropriate to remark at this point that the psychology of myasthenic patients is not infrequently abnormal The symptoms of the disease when they are severe are always humiliating and sometimes make the individual quite unfit for ordinary social intercourse This may not unnaturally result in making the patient morbidly conscious of his disabilities and in producing a general mental depression Sometimes he appears to have relapsed into a state of apathy and resignation and does not seem to care much what happens

Many patients on the other hand particularly those who are young are so eager to recover their normal powers that they will try from the outset to impress on their medical attendants the improvement they are showing, even when in fact, none has taken place Such patients will try by sheer will power to maintain that they can reduce their dose of neostigmine, or increase the interval between doses when really they need just as much as before It follows that questioning the patient as to his powers of exertion is not always a reliable guide to his progress Systematic tests must also be used

On the other hand some patients even when they ha e completely recovered, still believe they need occasional, or even regular doses of neostigmine because doing so gives them additional confidence particularly in the face of any stress It is then the act of taking the drug, as an ingrained habit which produces the result, and not its physiological action, which is of course nil in a normal person as regards the voluntary muscle system A good example of this was a girl who after she had quite recovered following a thymectomy used to take a tablet of neostigmine on a Saturday afternoon to help her as she believed through the evening s dance

Thymectomy in Relation to Thyrotoxicosis

Much emphasis has sometimes been laid upon the interrelation of myasthenia gravis and hyperthyroidism The asthenia of severe thyrotoxicosis has indeed sometimes been confused with myasthenia, and in a few instances it has even been claimed that a thyrotoxic asthenia has responded to treatment with neostigmine This is, however quite exceptional Usually neostigmine has no effect on the thyrotoxic patient, and if an effect is demonstrated then the probability of the co-existence of myasthenia gravis must be suspected The frequency of this relation seems to have been exaggerated In our own series of 140 myasthenic patients only one was suffering at the same time from severe thyrotoxicosis. A few others have had a mild degree of hyperthyroidism but the association has seemed to us to be fortuitous It is well known that in primary hyperthyroidism the thymus gland is often enlarged but this does not in the ast majority of patients, imply any abnormal action of the thymus and its true significance is unknown—unless it be merely one manifestation of the tendency to lymphoid hyperplasia that is found also in the hyperplastic thyroid gland Removal of the thymus has not been found to influence the associated hyperthyroidism

In the few patients showing both conditions who have come under our care, we ha e operated first on the thyroid gland This may entail a considerable risk, but it has not so far proved fatal in our hands and the second operation for thymectomy is undoubtedly safer for the patient who is no longer thyrotoxic.

RESULTS OF THYMECTOMY FOR MYASTHENIA GRAVIS

One of the most effective criticisms of the operation of thymectomy for myasthenia gravis is the uncertainty of the result. The operative mortality has been reduced to a low level but no one can predict the result for any given patient with confidence. It is also not easy to assess the results in a disease which is so varied in its clinical manifestations except in those patients who lose all symptoms after thymectomy and in those whose condition remains unaffected. We have therefore chosen to compute the results by dividing the patients into four arbitrary classes making two classes intermediate between those who are apparently cured and those who are unchanged. The categories and figures in a series of 84 patients who did not have thymic tumours, are as follows

	NUMBER	PER CENT
A. Quite well	26	31
B. Almost well some neostigmine still needed	27	32
C. Improved but dose of neostigmine still considerable	22	26
D. No change	9	1
TOTAL	84	

Certain generalisations can be made from a detailed analysis of the patients

1. The best results are likely to be obtained in the younger patients with short histories
2. The worst results will usually be among the older patients even though the history is not long. It is unusual to get appreciable improvement in any patient over 50 years old.
3. The fact most influencing the result apart from age is the length of the history: the longer the disease has been established the less likely is a cure to be obtained

These generalisations however cannot be regarded as rules. There are sure to be bitter disappointments as well as pleasant surprises and few patients can be rejected on this basis as unlikely to benefit. The elderly patients are clearly the most dubious and those over 50 years of age should seldom be subjected to thymectomy. In addition every patient, whatever the age should be warned that no improvement can be promised. Every operation is to some degree experimental though it is probable that in some of the apparent failures the disease which is frequently progressive when initiated may prove to have been arrested

Emphasis has already been laid upon the seriousness of the prognosis for those patients who are found to have thymic tumours. Some patients have shown a dramatic improvement after removal of tumours but usually this has been evanescent and they have relapsed and died within a few weeks, though no explanation of this has been found at autopsy. More encouraging results have been obtained in a few patients who have had deep x ray therapy followed by operation after an interval long enough for the skin reaction to subside. If as experience increases this should prove to be the best course of action, the importance of preliminary x ray diagnosis becomes the more plain

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CHAPTER 7

The Treatment of Empyema Thoracis

N R BARRETT

EMPYEMA THORACIS has been defined as a localised collection of pus in the pleural cavity but this definition excludes the formative stages of the process in which the patient often presents for treatment, and for this reason it is preferable and more practical to regard an empyema as a collection of liquid which has occurred as a result of acute inflammation and to refer specifically to the phase in which the inflammation stands

Empyema occurs concurrently with serious conditions in other parts of the body and arises as a spread of inflammation from a pneumonia a wound a pulmonary suppuration, or as a manifestation of septicaemia but it is seldom a surgical emergency in itself Treatment is dictated not only by the lesion in the pleural cavity but by the general state of the patient and in one suffering from septicaemia, for example survival depends more upon the virulence of the organisms and the efficacy of the antibiotics than upon the details of how the empyema will be treated But once the patient has halted or mastered the progress of the septicaemia the empyema which persists assumes a different importance It is then the principal abnormality with which the patient is afflicted Arranged chronologically the aims of treatment are to save life to cure the acute empyema, and to prevent complications

ACUTE EMPYEMA

GENERAL CONSIDERATIONS

Three principles dominate the management of acute empyemas to get rid of the pus to obtain complete re-expansion of the lung, and to restore the movements and function of the parietes to normal Failure to achieve these purposes may cost a life or herald chronic, and perhaps irreparable invalidism The proper sequence of treatments depends upon a number of variable factors so that there is no routine or schedule which can be applied to all cases.

Mode of Development of an Empyema

The mode of development of an empyema affects its treatment. The common variety occurs as a complication of pneumonia and is preceded by acute inflammation of the pleura from which an inflammatory exudate is poured out. The liquid is thin and slightly turbid at first. It contains polymorphs and bacteria and generally gravitates to the bottom and to the back of the pleural cavity but if the inflammation in the lung presents upon a fissure or abuts upon the mediastinum the pus which forms may be separated from the chest wall by normal pleura. The inflammation is at first a *cellulitis* and it is a general surgical principle that cellulitis is not properly treated by incision. There are other reasons why surgical drainage of the pleural cavity in the early stage of an empyema is dangerous. If the operation be done before localising adhesions have formed the lung becomes atelectatic, the visceral

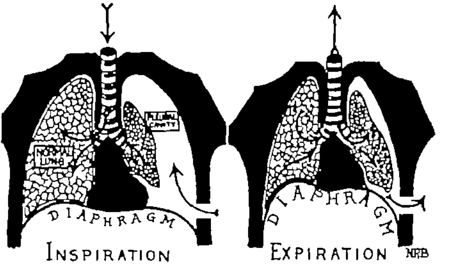

Fig. 99. Diagrams to illustrate the harmful effect upon respiration of draining an empyema too soon. The arrows indicate the direction of streams of air and it will be seen that the movements of respiration result in air being sucked in and pumped out of the open pleural cavity with the result that as the normal lung expands the other lung contracts and this causes anoxia by reducing the volume of fresh air available for ventilation.

and parietal surfaces of the pleura are separated and the inflammation is spread to the full limits of the space (Fig. 99). Sudden total empyema is a menace to life in itself as can be seen whenever a lung abscess ruptures into the pleural cavity. In addition an open pneumothorax is created at a time when the cardio-respiratory system of the patient is already taxed. For these reasons the treatment of an acute empyema is generally conservative at first but when the cellulitis has become converted to a localised collection of pus whose boundaries are firmly circumscribed the treatment can then be directed to the abscess.

Nature of the Pus in the Pleural Cavity

Pus which has collected in the pleural cavity seldom resolves spontaneously and active therapy is necessary to effect a cure. How this should be achieved depends upon the stage which the inflammation has reached, and much information can be

gained upon this score by examining the pus itself. Whenever the chest has been aspirated the liquid which has been withdrawn should be divided into two parts—the one to be sent to the laboratory for bacteriological investigation and the other to be kept in the ward. The ward specimen should be put into a sealed test tube and after it has stood for several hours the pus cells separate from the exudate and gravitate to the bottom of the tube; in the early stages of an empyema a small deposit collects but as the inflammation becomes walled-off in the pleura the ratio of pus to exudate increases.

A consecutive series of specimens (Fig. 100) is a reliable index of the progress of the inflammation in the thorax: thin pus denotes cellulitis, thick pus means localisation. Secondly the pus should be smelled. If the liquid is odourless no information

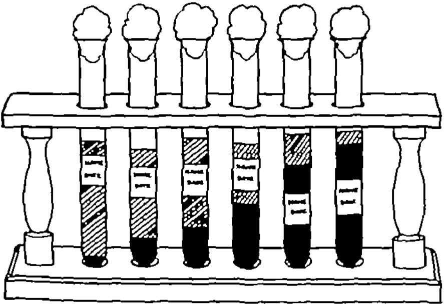

Fig. 100. A series of test tubes containing liquid aspirated upon successive days from a patient suffering from an early acute empyema. Each tube bears the name of the patient and the date of aspiration. That on the left shows a small sediment of pus (black) and a large amount of serum; the tube at the other end shows that the relative proportions of pus and exudate have changed and it is permissible to assume that the empyema is now ready for surgical drainage.

has been obtained but offensive pus suggests several probabilities. Foul pus is generally the result of some suppurative process in the lung, the mediastinum, or the abdomen which has ruptured into the pleura. If the organisms responsible are anaerobic spirochaetes, streptococci or the organisms of Vincent's angina the empyema has probably been caused by pulmonary suppuration. If the pus stinks but no organisms can be found actinomycosis may be the cause. If the smell be due to a mixture of *B. coli* and other organisms the original source has been the alimentary canal and a subphrenic connection may be suspected.

Finally *the pus must be cultured both aerobically* and anaerobically not only to exclude tuberculosis but because certain organisms engender a certain type of inflammatory reaction so that to some degree the course of the disease may be predicted. For instance pneumococcal empyemata localise early, the pus is thick

and creamy It contains large pieces of fibrin which do not drain easily and organisation begins early Streptococcal inflammations on the other hand, localise more slowly and the liquid in the pleural cavity may remain thin and turbid for a longer time The treatment of an empyema is importantly influenced by the sensitivity or otherwise of the organisms to sulpha drugs and antibiotics but the action of these chemicals should be directed against the organisms and not against the pus

The Age of the Patient

Another factor in treatment is the age of the patient. Empyema is more serious in an infant than in an adult because the thorax is small and the inflammation apt to encompass the whole pleura As a space-occupying lesion 200 c c of pus in the chest of an infant correspond to 3 litres in an adult, and for these reasons the mortality in babies is more than 60 per cent The chief problem is how to get rid of the pus because infants stand open surgical drainage badly and it is fortunate that chemotherapy and antibiotics are often effective in sterilising the exudate When *this has been achieved many can be cured by repeated aspirations alone This* applies particularly to some types of staphylococcal empyema (which commonly *complicates rupture of a staphylococcal lung abscess) but on occasion is adequate* for streptococcal and pneumococcal infections also If these conservative measures fail the acute emergency will have been weathered and surgical drainage can be undertaken with a greater margin of safety Intercostal drainage is the only type of closed drainage which is easy to manage in an infant

In old age empyema tends to mature insidiously so that by the time the diagnosis has been made the stage is already set for the development of a chronic empyema. The pus often occurs as a complication and perhaps as the presenting sign, of some serious pulmonary disease such as carcinoma of the bronchus and old people tolerate an empyema badly because it reduces the respiratory efficiency and because it involves a long period of illness

Essentials of Successful Therapy

Cure of an empyema does not depend upon the use of any special tube or gadget It rests firmly on the proposition that the surgeon should know what to do and when to do it Nor does treatment end when drainage has been achieved, but when the lung has completely expanded when the drainage sinus has healed and when the movements of the chest have been restored to normal Not all surgeons will agree with these remarks because Providence has decreed that some acute empyemata shall heal straight-forwardly irrespective of the treatment which has been used and regardless of all the rules But thoracic surgeons see the failures and are impressed by the hopeless plight of the patient whose empyema has been perpetuated by carelessness and for whom nothing but heroic surgery offers a chance of cure

PRINCIPLES OF TREATMENT

The principles of treatment of an acute empyema are

1 To locate the pus by paracentesis and to determine its confines
2 To ascertain the cause of the empyema and whether or not it still operates
3 To discover the type of inflammation concerned and the phase to which it has advanced

4 To identify the organism responsible remembering particularly that tuberculosis may be the cause
5 To evacuate the pus
6 To sterilise the cavity
7 To obtain early and complete expansion of the lung together with normal function of the cardio-respiratory system
8 To avoid a chronic empyema

Once pus has formed in the pleura it must be evacuated If there is no active treatment the body may succeed in mastering the general infection but the pus persists in the empyema and is a perpetual danger It may become walled-off and remain silent and apparently harmless for weeks months or years and such a collection has been aptly described as a tame lion It flares up at any moment More generally an untreated empyema ruptures into a bronchus and is coughed up or discharged intermittently through a sinus in the chest wall These probabilities are most strenuously to be avoided

CONSERVATIVE TREATMENT

Conservative treatment refers to all measures except surgical drainage

Paracentesis Thoracis

Aspiration is the first step in the treatment of all empyemata It is carried out partly for diagnostic purposes partly to gather the information which is necessary to assess the case and sometimes as a method of cure in itself The object is to prevent the pus compressing and collapsing the lung, and so to control and limit the size of the empyema During the phase of cellulitis aspiration is the proper and safe method of drainage and the exudate can be drawn off easily because it is thin The indications that paracentesis is necessary or that it must be repeated are that the liquid has caused the lung to collapse and is hindering respiration, or producing toxaemia and the proof that the treatment has been correct is afforded by an amelioration of the signs and symptoms and by the fact that the lung expands The frequency with which aspirations are necessary depends upon the rate at which exudate is accumulating in some cases it may be essential to draw it off once a day Aspirations must be replaced by other methods as soon as the pus has become thick so that efficient drainage can no longer be achieved Each time the chest is aspirated as much pus should be taken as can be secured without causing distress to the patient pain dyspnoea, and tachycardia are symptoms which indicate that enough liquid has been withdrawn for the time being Repeated aspirations of small amounts are preferable to occasional aspirations of large amounts for extremes of stretching and relief are harmful to steady resolution of inflammation

Paracentesis is not without dangers The least serious are syncope and nausea due to a natural dislike which most patients have for any form of needling More serious are air embolism (pleural shock) which can cause death or any type of central paralysis and pulmonary oedema The latter are rare but may occur if a large effusion is taken off too quickly from a toxic patient or if a high negative suction (such as can be obtained with various suction aspirators) is suddenly induced. Cough and broncho-pleural fistula are sequelae which can follow puncture of the

Appropriate antibiotics and sulpha drugs are an integral part of the treatment of all patients suffering from acute empyemata whether they be treated by repeated aspirations or not.

OPERATIVE TREATMENT

Intercostal Drainage

Intercostal drainage (Fig 102) is seldom used except in the management of special cases It is a way of securing more adequate and continuous evacuation of the

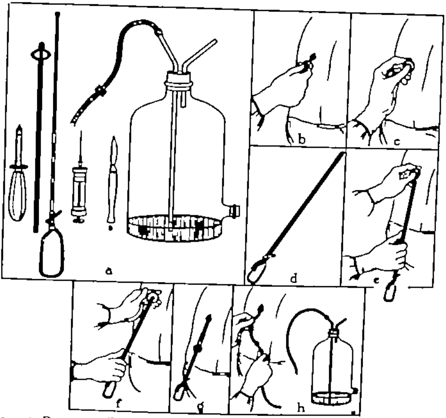

Fig 1 Diagrams to illustrate the technique of intercostal drainage This is minor operation which should be done in the ward under local anaesthesia The skin and the parietes are anaesthetised with t 40 ml of local anaesthetic (4); nick is then made in the skin using small scalpel (5) the trocar and cannula (1) are pushed through the chest wall into the empyema (*b*) the trocar is withdrawn and the thumb of the operator placed over the end of the cannula to stop air getting int the empyema ( ); an intercostal catheter (*d*) stretched upon a wire introducer (2) ntroduced int the empyema (*e–f*); the cannula is withdraw (*g*) and holding the intercostal tube the latter is connected to water seal (*h*)

pus than can be had by repeated aspirations but without the risks entailed by admitting air to the pleural ca ity Any method of introducing an intercostal catheter which allow air to enter the empyema and in which the catheter is not connected to a simple water seal apparatus defeats its own ends

Intercostal drainage is temporary expedient used in those cases in which repeated aspirations are fa ling to control the acute phase of the illness It is most apt in the management of infants in whom aspirations are difficult and rib resection dangerous

and it is valuable for empyemata which occur after major abdominal or thoracic operations and in which the patient is not yet fit mentally or physically for further surgical intervention It is a stop-gap which seldom cures the disease (because an intercostal space is not wide enough to admit a large enough drainage tube) but which may be a life-saving measure between aspirations and rib resection To introduce an intercostal tube under general anaesthesia and with all the paraphernalia of a major operation disposes of much of the value of the manoeuvre

Drainage by Rib Resection

Indications Drainage by rib resection is necessary in every case treated at first by aspirations or an intercostal tube in which thick pus begins to accumulate The operation must be performed as soon as the inflammation in the pleural cavity has localised—that is when the liquid aspirated shows a sediment on standing of more than 75 per cent of pus—and the tube which is introduced should be connected to a closed or water seal

Position of the Patient As a general rule the patient should lie for the operation in the lateral position and with the affected side uppermost but if a large broncho-pleural fistula is known to exist he should sit across the operating table with his feet and his arms on rests In this position the pus cannot run into the bronchial tree

Anaesthesia Local anaesthesia is most desirable because the patient, under general anaesthesia who happens to have an unsuspected broncho-pleural fistula is likely to drown in his own pus at the moment the empyema is opened This accident happens

Preliminary Aspiration to Determine Site of Drainage The drainage tube must be introduced near the bottom of the empyema considering that the patient will be nursed in the sitting position and that one of the desirable features of con alescence will be to get him up as soon as possible To discover the bottom of the empyema the affected area of the chest should be aspirated in successive intercostal spaces from below upwards until pus is secured There is no one particular site suitable for draining all cases but the one selected should be near the bottom of the cavity and between the posterior axillary and para ertebral lines

Surgical Approach with Rib Resection The incision in the skin and muscle layers should be 3 inches long and vertically disposed so that if it suppurates pus can ultimately escape downwards Two inches of the appropriate rib should be removed subperiosteally and the intercostal vessels exposed tied and cut out over a corresponding length The object of this is to reduce post-operative pain and to eliminate secondary intercostal bleeding

Initial Suction Drainage The initial incision through the parietal pleura and into the abscess should be just large enough to admit the nozzle of the suction tube At this point patients will react in one of two ways If timing of the operation has been accurate and localisation of the inflammation in the pleura is well set there will be no change in the clinical condition but if the empyema has been drained a little too soon the patient will cough, become dyspnoeic and cyanosed, and evince all the signs of an open pyopneumothorax In the latter event a closely fitting tube, connected to a closed drainage system should be put in and the operation concluded without delay

by maintaining a small continuous negative intrapleural pressure but, by draining away the pus avoids the necessity for frequent dressings When the discharge has become reduced to a few ounces daily and the patient is convalescent open drainage can be started by cutting the tube short at the chest wall and allowing the pus to drain into dressings This has the advantage that the patient can get up and encourages full expansion of the lung by taking exercise and using the muscles of respiration to the uttermost.

Post-operative Care Convalescence must be smooth and progressi e A high protein diet is necessary to replace the proteins lost in the exudate and fresh air stimulates and encourages the patient. The haemoglobin is often low and in some cases a small transfusion acts as a good tonic The assistance of a masseuse versed in the practice of inspiratory breathing exercises greatly increases the range of movement of the chest wall, teaches the patient to use all muscles of respiration to their maximum efficiency and not only diminishes the time between drainage and cure but ensures that the ultimate function of the cardio-respiratory system will be normal There is no place for exercises which rely on blowing air from one bottle to another

Assay of Progress towards Resolution. The progress towards resolution must be watched from day to day In a favourable case the lung expands quickly so that the volume of the cavity is reduced from several pints to a few ounces in a week. After this progress is slower and it is in judging when the last remnant of the pocket has been obliterated that most skill is required Some idea as to progress may be had by pouring saline into the cavity—the patient lying on his good side—and measuring the volume it contains Another way is to sound the ca ity using a large blunt pointed probe but the best is to introduce lipiodol and take serial radiographs. Whate er method is used the tube must continue to function as a drain until it is finally remo ed and it must not be removed until the last vestige of a pocket in the pleura is known to have been obliterated

PLEUROGRAPHY Pleurograms are made by laying the patient on the normal side taking out the drainage tube and inserting a slender catheter into the depths of the ca ity Lipiodol is injected through the catheter If the oil is introduced from a syringe straight into the drainage tube or into the sinus it may be prevented from reaching the main ca ity by an air lock. The object is to coat the walls of the space with the oil and not to fill it to overflowing The catheter is then removed and a fine p ece of leaded rubber equal in length to the drainage tube is fixed in the sinus the orifice of the latter is plugged with gauze and a small metal ring is placed upon the skin to mark the orifice of the sinus The patient is then turned about in various directions and radiographs taken in the postero-anterior and lateral positions The films show the size and shape of the cavity (Fig 105) and the leaded rubber demonstrates the li of the drainage tube relative to the bottom of the empyema. The onl danger of this in estigation is the possibility that the patient may be sensiti e to iodine Both lipiodol and neo-hydriol contain 40 per cent of iodine in poppyseed oil Reactions are fortunately rare but occasionally cause serious con stitutional signs such as pyr xia anorexia coryza, injection of the eyes puffiness of the face and dermatitis in the form of blisters esicles or pustules Sensiti ity to iodine can be tested in doubtful ases by gi ing potassium iodide 10 grains three times a day for twenty four hours before doing a pleurogram

Points to Be Remembered in Draining an Empyema Whenever a tube is inserted to drain an empyema these points must be remembered: the tube is a foreign body in a septic field It function is to drain away pus without perpetuating the empyema or causing a cellulitis of the chest wall A tube which does not drain is not properly placed or is blocked with pus It should be changed or adjusted Whenever pus leaks around a tube that tube is no longer functioning as a drain but as a septic bung A tube which is painful is of the wrong size the wrong length causing an inflammation along the track or is not securely held A tube must be held so that it moves neither in nor out and the method of fixing must be simpl no gadgets are

Fig 5 A well-made pleurogram which show the outlines of hronic empyema cavity No attempt should be made to fill the cavity with the radiopaque solution but the walls should be outlined as shown in this radiograph.

required A tube that is not securely fixed will come out or more likely be sucked into the empyema and lost The simplest possible tube is the best tube to use flanged tubes hinged tubes, tubes containing valves and the like are all advocated by the tyro but discarded by the expert.

Spreading Gangrene of Skin as Complication (Fig 106) A tube draining an empyema occasionally gives rise to spreading gangrene of the skin This occurs particularly in debilitated elderly patients and starts as a carbuncular eruption without much pain or general disturbance in the superficial end of the tube track The treatment consists in gi ing sulpha drugs and antibiotics in removing the tube (the sinus will not close as long as the inflammation is uncontrolled) and in widely excising the

lesion down to healthy tissue The raw surface is covered with a zinc peroxide dressing and as soon as the infection has been controlled the healthy granulations are grafted and the drainage tube *reintroduced* *Untreated, spreading gangrene of* the skin marches slowly forward and ultimately the patient dies from pain exhaustion and toxaemia

Fig 06 Photograph of patient with spreading gangrene of the skin which started in stitch *hole nine days after drainage of streptococcal empyema The patient was eventually cured by* excision of the gangrenous area (J W S H Lindahl St Thomas Hospital Report ; 2nd series, 936 Vol)

Decortication

Indications Decortication which was formerly regarded as a sound treatment for chronic empyema is practically obsolete except for some cases of tuberculous *empyema but is indicated as the method of choice* in the management of some cases of infected haemothorax of some cases of post pneumonic total or loculated empyema, and of empyema associated with or caused by pathological conditions affecting the upper lobe of the lung

In these the whole pleural cavity is generally infected from the outset and

routine treatment by aspirations antibiotics and drainage is apt to fail because the upper lobe does not re-expand as quickly as the lower parts of the lung and so does not fill the dome of the pleural cavity An apical empyema is formed in this way and is more difficult to cure than a basal lesion because the forces which tend towards re-expansion of the lung are less effective at the top than at the bottom of the chest In some cases and particularly when wounded the upper lobe topples over on the hilum as a result of its weight and the original apex of the lung can become adherent to the diaphragm anteriorly If for any reason re-expansion of the upper lobe is delayed, the exudate upon its surface organises and binds it down so effectively that however efficient drainage may be a chronic apical empyema occurs It is primarily to avoid this event that decortication is practised during the acute phase of the inflammation.

Decortication should achieve another benefit, namely elimination of the infection To be successful the lung must be capable of expanding totally at the end of the operation and must be kept expanded until the danger of reinfection in the pleura has passed The operation fails in most chronic empyemata because after the lung has been held down and invaded by scar tissue for any length of time the scar cannot be adequately stripped off and even when it is decorticated the lung cannot be re-inflated because of interstitial fibrosis

Technique The patient is given a general anaesthetic and a blood transfusion is set up the pleural ca ity is opened through a large intercostal incision so placed that all parts of the empyema are accessible. Pus fibrinous masses blood clot and debris are sucked out from the empyema and the lung will be seen encased in a dense opaque inflammatory membrane This membrane prevents respiratory movements and ensheathes the pericardium, the diaphragm and the chest wall It is the breeding ground of all the relevant organisms The membrane is incised on the surface of the lung until the blue-grey pigmented pulmonary tissue is exposed at the bottom of the incision A plane of cleavage can generally be found between the lung and the membrane and the latter is stripped off by blunt dissection, using small gauze swabs. During this part of the operation the lung may be injured in several places but the al eolar fistulae which result are of no significance and close spontaneously they may with ad antage be covered with fibrin gauze.

Decortication must include the whole lung (excluding a small area immediately adjacent to the hilum) the diaphragm and the chest wall The two latter should be decorticated because normal movements of the apex of the lung depend largely upon the diaphragm and because the organised exudate which fills the costophrenic sulcus prevents the lung descending to its normal limits At the end of the operation the anaesthetist should be able to inflate the lung to its total capacity and there should be no macroscopic evidence of inflammation anywhere The thoracotomy incision is closed completely in layers but two drains are left in the pleural cavity

The operation described above is a serious undertaking and success will be in danger unless the lung can be held expanded for three or four days; it is toward the achievement of this objective that all subsequent treatment is directed. Penicillin and sulpha powder are left in the pleural cavity and exhibited by injections during convalescence but success does not hinge on their presence The drainage tubes have two purposes The first is a basal drain and underwater seal its function being

to deal with the exudate which always accumulates after the operation. The second is an intercostal catheter introduced at the extreme apex of the pleural cavity and connected to a suction apparatus—the object being to ensure that the last pocket of air at the top of the chest is taken off Both tubes are kept in as long as broncho-pleural fistulae persist, but both are taken out as soon as the lung is totally expanded that is on the second or third post-operative day

It will be found that the clinical condition of the patient is straightway alleviated by the operation, that the liquid which discharges post-operatively from the pleural surfaces is generally sterile that the thoracotomy incision heals by first intention, and that the patient is convalescent within a few days If infection does reappear the new empyema is generally of a simple basal type which must be managed on ordinary lines but the patient has been spared the complications of either total or apical empyema.

This operation carries an appreciable immediate mortality and for this reason it must be reserved for special cases

CHRONIC EMPYEMA THORACIS

DEFINITION AND DESCRIPTION

A chronic empyema is present as soon as healing of an acute empyema has stopped or slowed down to such a degree as to be imperceptible Every chronic empyema *(excluding tuberculous lesions)* was at first acute and every chronic empyema can be avoided by treating the acute phase correctly

Healing of an acute empyema depends upon two separate processes. In a favourable case practically the whole cavity which contained the pus is obliterated within a few days of drainage by expansion of the lung, and only the last little pocket by *fusion of the granulation tissue at the points where visceral and parietal layers meet* If the pus is not drained early and efficiently expansion of the lung is held back by fibrin deposited and organising upon its surface and healing then depends upon the slow and uncertain method of fusion from the edges If healing stops for any length of time the fibrin becomes organised to scar tissue and from then onwards the cavity can never obliterate by natural means *The problem is identical with that* presented by a chronic bone abscess

The treatment of a fully fledged chronic empyema is one of the most difficult in surgery The patient is suffering not only from the local effects of a large chronic abscess but from gross skeletal deformities toxaemia and abnormal function of the cardio-respiratory systems The lung is bound down by fibrous tissue which rigidly prevents movement and which invades and replaces the interstitial tissue (Fig 107) The scar which may ossify extends throughout the parietal walls of the cavity and may be as much as 2 inches thick It immobilises the mediastinum and the diaphragm it fixes and deforms the chest wall This dense fibrous bag is lined by septic granulation tissue and the pus secreted discharges spasmodically through a sinus in the chest wall or ruptures into the lung and is coughed up The contractions which occur produce lateral curvature of the spine whose concavity is towards the side of the empyema The whole of the affected hemithorax is flat and moves badly *on respiration* the ribs become triangular in shape (Fig 108) and fat is deposited beneath the periosteum they fuse together forming a solid carapace of bone The

respiratory efficiency is low and dyspnoea a prominent symptom The shoulder girdle on the affected side is stiff its movements are limited and it is held lower than its fellow the muscles are wasted and painful Generalised oedema pulmonary osteo-arthropathy chronic arthritis and peri-articular changes are common and crippling accompaniments Unchecked the disease advances relentlessly and death occurs at long last from exhaustion chronic toxaemia cardio respiratory failure amyloid disease (if tuberculosis has been added to the chronic sepsis) or cerebral complications such as brain abscess

PROPHYLACTIC TREATMENT

The most important thing about the treatment of chronic empyema is never to let it happen and hence the necessity for attention to detail in the management of the acute stage The factors which cause an acute empyema to become chronic are as follows

Fig 1 7 The chronic empyema patient. These photographs show that a long-standing chronic empyema produces great general changes as well as those which occur in the pleural cavity and adjacent thoracic structures.

1 The acute empyema has been ineffectively or wrongly drained Either the method or the timing of treatment may have been at fault.
2 The acute empyema has been perpetuated because it contains a foreign body
3 Specific organisms such as the tubercle bacillus the diphtheria bacillus or the streptothrix of actinomycosis are responsible
4 The empyema is maintained by a persistent pathological condition in the lung
5 The empyema is a complication of malignant endothelioma of the pleura

Inadequate, Ineffective, or Badly Timed Drainage of the Acute Empyema

The dangers of draining an acute empyema too soon are that the patient may be killed by the operation or that a local empyema may be converted into a total empyema The dangers of draining too late are that the septic membrane which encases the lung holds it down so that rapid re-expansion is prevented the masses

of fibrin accumulate in the pus and not only hinder drainage but favour loculation A common reason for deferring drainage is that the patient seems to be responding

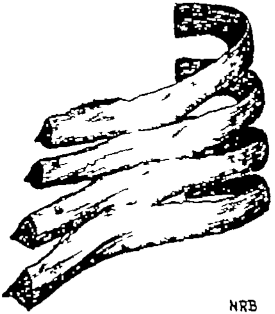

Fig 1 Parts of four ribs removed at operation from patient suffering from hronic empyema. The ribs are fused together by bone: the surfaces are roughened by new bone formation and the shape of each rib, in transverse section, has been changed from flat to triangular These ribs were not in ontact with the cavity of the empyema

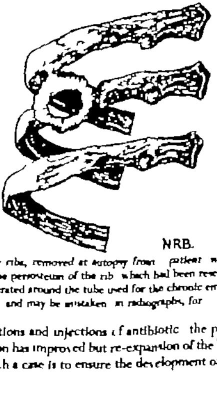

Fig 09 Parts of three ribs, removed at autopsy from patient who had had drained for long time The periosteum of the rib which had been resected t acute empyema, has regenerated around the tube used for the chronic emp bone may impede drainage and may be mistaken in radiographs, for

well to repeated aspirations and injections of antibiotic the pus l and the clinical condition has improved but re-expansion of the lun To defer drainage in such a case is to ensure the development of a cl

Assuming that proper drainage has been applied at the proper time a chronic empyema may occur because drainage has become inefficient during convalescence and the causes of this are as follows

1 *The tube is blocked* because it is kinked or obstructed by thick pus or masses of fibrin in the lumen Another common reason is that a side hole has been cut in the tube and into this granulation tissue has grown; never cut a side hole in a tube inserted to drain an empyema for the reason mentioned above and because if the tube is patent all that part above the side hole is a redundant septic foreign body

2 *The tube is too long* The inner end should lie at the bottom of the cavity it is set to drain and to achieve this position a constant check by radiographs and direct inspection of the sinus must be kept A tube which projects above the level of the pus can only drain by overflow

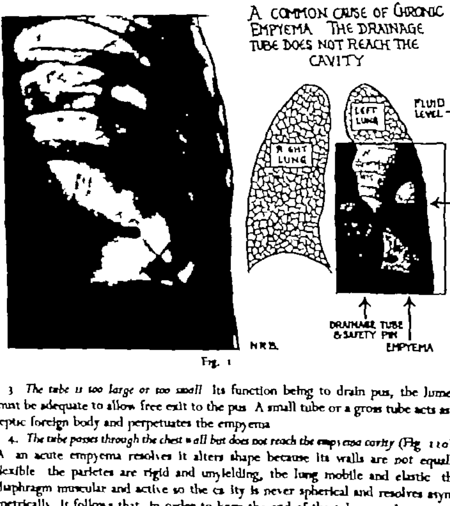

Fig. 1

3 *The tube is too large or too small* Its function being to drain pus, the lumen must be adequate to allow free exit to the pus A small tube or a gross tube acts as a septic foreign body and perpetuates the empyema

4 *The tube passes through the chest wall but does not reach the empyema cavity* (Fig 110) As an acute empyema resolves it alters shape because its walls are not equally flexible the parietes are rigid and unyielding, the lung mobile and elastic the diaphragm muscular and active so the cavity is never spherical and resolves asymmetrically It follows that in order to keep the end of the tube seated accurately in the bottom of the cavity constant adjustment is necessary The tube must often be lengthened as the empyema retracts away from the drainage site (Fig 111)

5 *Part of the empyema is not adequately drained* In some cases the shape of an empyema is such that two tubes are needed this can happen if the cavity is stretched

of fibrin accumulate in the pus and not only hinder drainage but favour loculation. A common reason for deferring drainage is that the patient seems to be responding

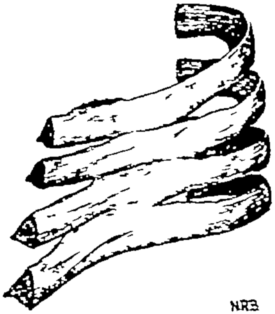

Fig. 48. Parts of four ribs removed at operation from a patient suffering from a chronic empyema. The ribs are fused together by bone, the surfaces are roughened by new bone formation and the shape of each rib in transverse section, has been changed from flat to triangular. These ribs were not in contact with the cavity of the empyema.

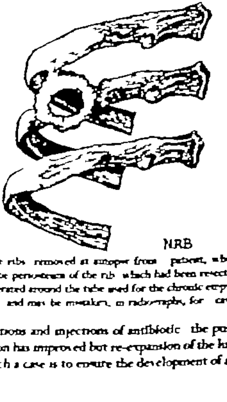

Fig. 49. Parts of three ribs removed at autopsy from a patient, who had had an empyema drained for a long time. The periosteum of the rib which had been resected to drain the original acute empyema, has regenerated around the tube used for the chronic empyema. Such regenerated bone may impede drainage and may be mistaken, in radiographs, for a cavity in the lung.

well to repeated aspirations and injections of antibiotic, the pus has been sterilised and the clinical condition has improved but re-expansion of the lung has not occurred. To defer drainage in such a case is to ensure the development of a chronic empyema.

Assuming that proper drainage has been applied at the proper time a chronic empyema may occur because drainage has become inefficient during convalescence and the causes of this are as follows

1 *The tube is blocked* because it is kinked or obstructed by thick pus or masses of fibrin in the lumen Another common reason is that a side hole has been cut in the tube and into this granulation tissue has grown never cut a side hole in a tube inserted to drain an empyema for the reason mentioned above and because if the tube is patent all that part above the side-hole is a redundant septic foreign body

2 *The tube is too long* The inner end should lie at the bottom of the cavity it is set to drain and to achieve this position a constant check by radiographs and direct inspection of the sinus must be kept A tube which projects above the level of the pus can only drain by overflow

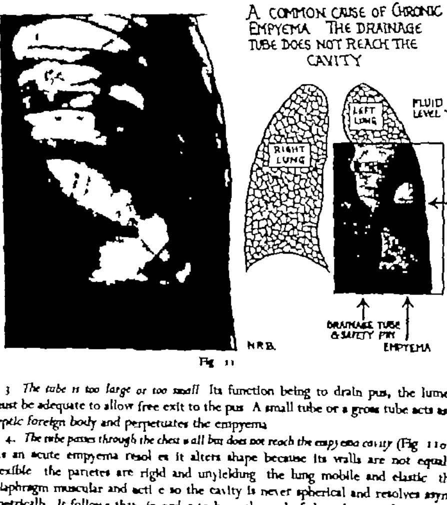

Fig 11

3 *The tube is too large or too small* Its function being to drain pus, the lumen must be adequate to allow free exit to the pus A small tube or a gross tube acts as a *septic foreign body* and perpetuates the empyema

4 *The tube passes through the chest wall but does not reach the empyema cavity* (Fig 110) As an acute empyema resolves it alters shape because its walls are not equally flexible the parietes are rigid and unyielding the lung mobile and elastic the diaphragm muscular and active so the cavity is never spherical and resolves asymmetrically It follows that in order to keep the end of the *tube seated accurately* in the bottom of the cavity constant adjustment is necessary The tube must often be lengthened as the empyema retracts away from the drainage site (Fig 111)

5 *Part of the empyema is not adequately drained* In some cases the shape of an empyema is such that two tubes are needed this can happen if the cavity is stretched

out along the upper surface of the diaphragm if one horn passes upwards in the paravertebral gutter whilst the other reaches forwards along the diaphragm; or if a cul-de-sac lies below the tube

6 *The site chosen for drainage has been wrong* A tube introduced after resection of the 11th or 12th ribs is almost certain to be ineffective because the diaphragm rises

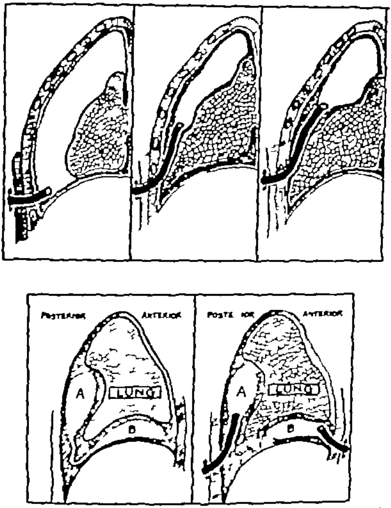

Fig The three diagrams at the top illustrate the point that as the lung expands and an empyema resolves it may be necessary to *lengthen* the drainage tube in order to keep its inner end at the bottom of the cavity This applies particularly to apical pockets.

The two diagrams at the bottom show that as the lung expands the empyema may become loculated so that several drainage tubes may be needed

and because the costophrenic sinus is obliterated by adhesions. A tube inserted too far forwards becomes ineffective as the last part of the cavity retracts towards the paravertebral gutter and a tube inserted too high can drain only by overflow

The only way to avoid these pitfalls is to pay attention to detail and the most useful adjuncts to keen observation are a stout probe (a uterine sound serves the purpose) a malleable light and the empyema sound devised by Allison (Fig 112)

Whenever doubt as to the efficacy of a tube arises it should be taken out and the track inspected Antero-posterior and lateral radiographs may afford additional evidence

The tube should be removed cleaned sterilised and replaced at frequent intervals; a sore skin a rusty safety pin and a painful polyp of granulation tissue round the tube indicate neglect and presage chronic empyema If pus runs out from the sinus after the tube has been removed this means that obstruction is present, and that the whole set-up of drainage must be reviewed In the early stages of drainage the track will close down almost as soon as a tube is taken out the wise surgeon, who wishes to change a tube will have a sterilised duplicate ready so that as one is removed the other can be introduced It is unwise to force a passage along a track which has partially obliterated the dangers of sudden dilatation are air embolism septicaemia and cerebral abscess The safest way of dilating the lumen of a sinus so that it can take a larger tube is to introduce a fine laminaria tent and to leave this in place for twenty-four hours A track should never be dilated forcibly with a finger a sound or a bougie

A common cause of chronic empyema is removal of the drainage tube before the empyema cavity has obliterated As long as any pocket of pleural suppuration persists drainage must be maintained The most accurate way of assessing when to take the tube out

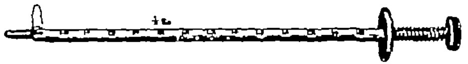

Fig 1 Allison empyema sound which is used to measure the exact length of the track in the chest wall leading to an empyema and so to adjust the length of the drainage tube

is to make pleurograms by instilling lipiodol into the track and when no oil penetrates beyond the sinus in the chest wall the need for drainage has ceased If drainage is ended too soon the sinus will heal at first, and may remain healed for years during which time the patient gradually develops all the changes of a chronic empyema

Presence of a Foreign Body in the Acute Empyema

This is a definite but unusual cause of chronicity and the foreign bodies concerned are of two types When an acute empyema is treated by rib resection and drainage the cut ends of the rib from which a segment has been removed are bathed in pus and may develop an osteitis which proceeds to sequestrum formation Spicules of dead bone are sometimes found in chronic empyema and are sufficient to perpetuate sepsis To prevent this surgeons have advised coating the cut ends of the rib with bone wax before opening the acute empyema.

The other cause is a tube which has been sucked into the cavity and disappeared (see Fig 113) The history of such a case is typical The tube is inadequately fixed and breaking loose enters the empyema the patient is not aware of what has happened surgeons or nurses who examine the wound assume without telling the other person that the tube has for one reason or another been removed. A new tube is inserted and nobody worries about the old one But the old one may remain undiscovered in the cavity for many years and be the instigator of hopeless deformi

ties and chronic ill-health. Not every tube shows in a radiograph and even if the offending tube does show the radiologist may not mention the fact because he does not know the problem and because he assumes that the tube he can see is there for some surgical purpose. It is an unfortunate fact that by the time most of these cases are discovered removal of the tube only solves half the problem.

Fig. 1 3. Radiograph of the chest of a man suffering from a chronic empyema. Twenty years previously he had been wounded in the chest and developed an empyema which was treated by drainage with a tube. Drainage was given up but the empyema persisted. This radiograph taken twenty years later shows the results of several attempts at closing the empyema by lateral thoracoplasties, but it also shows the cause of the chronic empyema, namely that *the original tube was lost in the empyema cavity.*

Specific Organisms as Cause of Chronic Empyema

The case referred to is not that of the patient who is known to suffer from pulmonary tuberculosis, diphtheria or actinomycosis, but one in which he develops an acute empyema that, in spite of meticulous treatment, does not proceed evenly towards resolution. These may be cases in which the specific organisms have been present from the start or have entered the septic field as secondary invaders. The organisms may or may not be demonstrable in the pus which discharges from the cavity, but if present are most certain to be found by examining the granulation tissue in the walls. For this reason whenever an acute empyema is drained, a small

piece of the inflamed parietal pleura should be taken for biopsy examination and culture The culture should specifically provide circumstances suitable for growth of the tubercle bacillus and actinomycosis

Perpetuation of the Empyema by a Pathological Process in the Lungs

Two types of lesion occurring in the lung can induce an acute empyema and prevent its resolution In both the clinical diagnosis may be fogged because the presenting *signs and symptoms are often not referable to the lung even if malignant* disease be the cause In both, the basic factor is that the cause of the inflammation persists The first are those associated with bronchial obstruction and the second are inflammatory occurring in conditions such as lung abscess bronchiectasis and infected lung cysts

Any part of the bronchial tree may be obstructed by a block in the lumen of a bronchus (such as an inhaled foreign body) a block caused by a lesion in the wall of the bronchus (such as an adenoma or carcinoma) or by pressure from without (such as by an enlarged lymph gland) The bronchial tree resembles the duct of any other hollow viscus in that obstruction leads to accumulation of secretions behind the block and ultimately to infection. The infection spreads from the lung to the pleural cavity and is perpetuated by communications—broncho-pleural fistulae—which develop between the bronchial tree and the pleural space It is a common fallacy to believe the empyema will be cured if the broncho-pleural fistula can be excised or sewn up the truth is that fistulae will close spontaneously if the cause be taken away

The second group differ from those described above because the bronchial obstruction which causes the fistula to develop and which initiates the empyema, is not permanent The type of lesion concerned is the putrid lung abscess and in the majority of these cases the sloughs of lung and other contents of the abscess are too massive to be evacuated by the bronchial tree Another example is the lung cyst which becomes infected and surrounded by pneumonitis so that the draining bronchi are blocked by oedema or congestion In these the initial cause of pleural suppuration is temporary bronchial obstruction but the empyema is perpetuated by smouldering or subacute inflammation in that part of the lung which was originally abnormal

These types of chronic empyema differ at first sight from those due to faulty drainage because it seems that they cannot be avoided but in this there is only a grain of truth The point is that, even though the patient may have no signs or symptoms of bronchial obstruction or lung disease the acute empyema does not resolve progressively and the surgeon should not wait months or years before beginning to enquire into the cause The treatment is to drain the acute empyema, and to follow this up *before the patient has developed all the deformities and disabilities of a chronic empyema* with measures appropriate to eradication of the cause

Endothelioma of Pleura as Cause of Chronic Empyema

Endothelioma of the pleura is complicated by chronic empyema when the malignant process is not diagnosed The patient suffers from the superficial deformities of a chronic empyema having a dull immobile and airless hemithorax the

radiographs show a diffuse and often extensive opacity and pain is a prominent symptom The malignant tissue which replaces the pleural membranes secretes a liquid containing debris and necrotic growth which superficially can resemble pus A diagnosis of chronic empyema is made in error pus is withdrawn on aspiration and drainage is instituted From then onwards the patient endures the miseries of a chronic empyema added to those of malignant disease and no treatment of either condition is of any avail

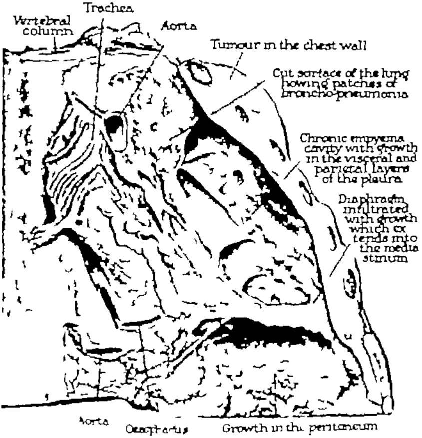

Fig 4 Post mortem appearances of the back of the left chest of a patient who died from malignant endothelioma of the pleura A chronic empyema had been diagnosed clinically and drained.

TREATMENT OF AN ESTABLISHED CHRONIC EMPYEMA

The essence of treatment is to discover and remove the cause, to obliterate the chronic abscess cavity and as far as possible to correct the deformities which have occurred

History and Clinical Examination

Consider a typical case The patient gives a history of having had an acute empyema treated several months, or years previously The tube was removed after a short period of drainage because the discharge seemed to be drying up but the sinus never healed properly and has continued to drain pus intermittently ever since

The first step is a thorough clinical examination to determine the extent of the problem not only as regards the empyema but in relation to the general health and disabilities of the patient. Radiographs of the chest (antero-posterior and lateral films) and a blood count to assess the degree of anaemia should be made. Sputum if present should be cultured.

Free Drainage of Pus Plus Supportive Measures

The empyema itself should then be investigated. If the sinus is narrow a small laminaria tent is introduced and left in for twenty four hours. It can then be replaced by a bigger tent and when that is taken out a large tube can be introduced providing free open drainage. The first specimen of pus which drains from the chest when the laminaria tent is taken out should be cultured aerobically and anaerobically. If the patient has been ill, anaemic or debilitated no further surgery should be done until the improvement which follows free drainage of the pus, associated with blood transfusions and other supportive measures, has accrued. This may mean a delay of a week or more and during this time physiotherapy should be started.

Physiotherapy

Throughout the surgical treatment of chronic empyema inspiratory breathing exercises are important and beneficial. As soon as the patient can get out of bed he should be encouraged to do so and should embark upon a vigorous course of exercises designed to regain the maximum movement of the chest wall, to use the abdominal muscles of respiration to their utmost, and to overcome stiffness and deformities in the shoulder girdle, the neck, and the spine. Nobody would deny the value of breathing exercises but the deep breathing produced by work, running, or walking is more valuable therapeutically than anything the masseuse can accomplish. It is most gratifying to see the way in which painful and immobile joints may be brought back to full function once the source of toxaemia has been drained.

Information to Be Obtained at Redrainage Operations

The next step is to verify the efficacy and the accuracy of drainage and to do this pleurograms should be made. In practically every case it will be necessary to re-drain the empyema at its most dependent point or at least to enlarge the sinus more than can be achieved with a laminaria tent. Redrainage operations should be done under local anaesthesia. During the operation the following additional steps must be taken. First, the opportunity should be used of examining the interior of the empyema cavity which is provided by the redrainage operation. Generally the incision in the parietal pleura will be large enough to allow direct inspection with a malleable light, but if some corner cannot be seen in this way a thoracoscope (or a cystoscope) should be introduced. The object is to ascertain first if there is a foreign body in the cavity (safety pin, sequestrum, tube or the like); if so, it should be taken out. Secondly, one must ascertain whether a broncho-pleural fistula is present and if so in which part of the lung it is situated. A fistula may be difficult to see if temporarily covered with fibrin: the patient should be asked to hold his nose and raise the air pressure in the bronchial tree by blowing out his cheeks. If doubt still exists the manoeuvre should be repeated after he has inhaled some tobacco smoke. The presence of a fistula means that a full investigation of the

lungs will be necessary as the cause of the chronic empyema may be disease in the lung. *The third point upon which information is required is on the thickness of* the organised fibrin on the surface of the lung and upon the chest wall. Does the lung move on respiration?

The second type of information which must be acquired at the redrainage operation is to find out the organisms concerned and to remove adequate pieces of the visceral and parietal pleura for biopsy and culture. In most cases the surgeon will proceed to make bronchograms of the affected side of the chest and to do a bronchoscopy; when these things have been done the cause of the chronic empyema will be known and curative treatment can be started.

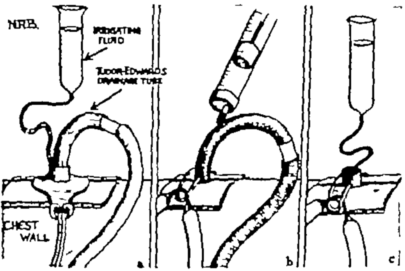

Fig. 5. Diagrams to illustrate three alternative methods of irrigating the pleural cavity.

Using Tudor Edwards drainage tube.
b Using the ordinary closed drainage tube.
Using an open drainage tube.

Pneumonectomy or Lobectomy in Cases of Permanent Lung Disease

If the chronic empyema is due to a bronchial adenoma or carcinoma the treatment is to remove the lung or the lobe concerned without further ado. It is useless and harmful to prolong the illness by treating the empyema any more without removing the abnormal lung. The same is true of cases due to bronchiectasis, infected lung cysts and other types of chronic suppurative pneumonitis. When the cause has been removed the problem is simplified: it is how to get the residual infected pleural space to heal and obliterate. It sometimes happens that an acute empyema is the presenting sign of a carcinoma of bronchus in an old person and that it is drained before the diagnosis of carcinoma has been made. The patient cannot be cured and the maximum relief will be achieved by maintaining free pleural drainage and encouraging the patient to get about with a tube in situ. A properly fitting tube is no bar to full and normal activity.

Procedure in the Ordinary Case

If the empyema is not due to permanent lung disease the first step is to try the effect of efficient pleural drainage (Fig 115) and physiotherapy and in many these measures alone will achieve healing Progress of treatment must be checked by serial pleurograms and drainage maintained until the empyema is obliterated Healing will be slow and tedious but as long as there is demonstrable progress towards resolution the patient should be encouraged to carry on, for results achieved in this way are superior to those given by complicated surgical operations

"Chemical Decortication"

Expansion of the lung can be helped on occasion by irrigating the cavity with chemicals (such as Dakin s solution) whose function is to produce chemical

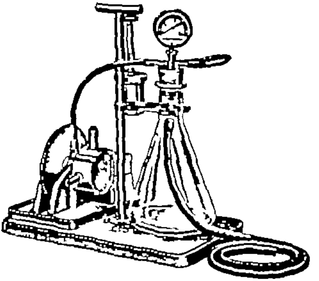

Fig. 6 Electric suction pump as used in the treatment of some cases of chronic empyema.

decortication The merit of this procedure is doubtful but, practically irrigations must never be used if a broncho-pleural fistula is present and in no circumstances must the liquid be introduced under pressure Irrigations should be done by passing a soft rubber catheter down the lumen of the drainage tube or along the drainage sinus the catheter must be much smaller than the tube or the sinus so that as the irrigation fluid is run in air displaced from the cavity can escape round the catheter

"Suction Drainage"

Another adjuvant is suction drainage to do this the patient must have a closed drainage system connected to a suction drainage pump (Figs 116 117) and remain in bed For this reason most surgeons are not in favour of suction drainage but prefer that their patients should be ambulant and active Small portable suction devices can be arranged but are of doubtful value

Late Cases

Continuous efficient drainage will cure practically all cases of *early* chronic empyema. Late cases will require additional surgical operations but even in these the general condition will have been greatly improved and the empyema cavity much reduced in size.

Small Cavities. If after efficient drainage a small cavity (i.e., capacity less than 100 c.c.) persists at the bottom of the chest this should be treated by *de-roofing*. This operation is done under general anaesthesia and the structures superficial to the empyema are taken away so that the infected space is laid open. At the conclusion the wound is packed and within a few days the surface of the lung ceases to

Fig. 7. Photograph showing patient suffering from chronic empyema being treated by continuous suction drainage. *The apparatus depicted is small, simple, compact, efficient and silent.* The pump is driven electrically.

discharge pus and looks clean. Healing by granulation occurs and can be expedited with appropriate skin grafts applied directly to the membrane on the lung.

Operations of this type cure small empyemata, but can be used only in certain anatomical situations: they leave an unstable area of *chest wall which moves paradoxically* on respiration and can cause dyspnoea on exertion. For these reasons some surgeons prefer *muscle grafts*. The empyema cavity is exposed by removing the overlying ribs; it is opened and filled by a graft taken from any large muscle in the vicinity. The graft is dissected in such a way that the base contains its nerve supply intact and an ample blood supply; its function is to fill the dead space between the visceral and parietal walls of the cavern. Operations of this type are successful in

spite of the fact that the graft is sewn into a septic space Antibiotics have greatly improved the results

Large Cavities Large chronic empyema cavities are difficult to cure and it is only during the last few years that good results have been achieved In the past reliance was placed upon various types of *lateral thoracoplasty* (Schede E tlander Wilms Sauerbruch and others) but none of these is reliable and all are severe and dangerous operations *Decision of the pleura* and *decortication* are also obsolete procedures for chronic empyema, because both rely upon total re-expansion of the lung and neither achieves this purpose in long-standing cases

Three objects must be achieved if a large chronic empyema is to be closed surgically the walls of the cavity must be apposed (either by mobilising the parietes or by securing re-expansion of the lung) sepsis must be eliminated (by excising the tissues in which the organisms live) and primary healing of the operation field must be secured These objectives cannot always be attained and the end result is deficient by the measure of their failure

FLAP OPERATION OF ROBERTS The best operations available at present are based upon the flap method devised by Roberts one which is applicable to most cases will be described The patient is given a general anaesthetic and a blood transfusion is set up The initial incision is small and encircles the drainage sinus and the bottom of the empyema cavity is opened widely enough to allow an assessment of its anatomy and dimensions The skin incision is then extended in the appropriate direction so that the ribs which overlie the empyema can be removed subperiosteally This leaves a thick sheet of tissue composed of periosteum, intercostal structures dense scar and granulation tissue (but without any bony struts) superficial to the empyema and through the front edge of this sheet an incision is then made into the cavity thus creating a flap of chest wall hinged posteriorly The next step is to cut out all the granulation tissue and as much of the fibrous tissue which formed the walls of the empyema as possible This not only allows the walls to be apposed but sterilises the wound by removing the tissue in which practically all the organisms live The flap thus formed from the parietes is sewn down to the mediastinum and to the surface of the lung with stitches of thread silk or steel wire This operation resembles decortication in that the aim is to remove most of the scar and most of the infecting organisms from all the walls of the cavity but *it differs importantly from decortication* in that success depends upon primary healing between the apposed tissues and not at all upon re-expansion of the lung Penicillin and sulpha powder may be left between the two layers The skin is closed with interrupted stitches and if drainage be used it should be to evacuate serum or haematoma for twenty four hours This operation carries a high percentage of successful results but it is severe and may ha e to be done in stages Blood transfusions and other supportive measures to a old shock are essential and during convalescence the patient must undertake a course of remedial exercises

STOMA OPERATIONS There are patients whose disease is of such long standing and whose deformities are so set that nothing more than alleviation of the symptoms can be attempted In such drainage must be adjusted and corrected and the patient must continue in this way for the rest of his life To carry an empyema drainage tube in the chest wall is no bar to an active life but has the disadvantages that

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dressings must always be secured and changed that the tube must periodically be removed and cleaned and that the patient cannot lie down in a bath. In some cases the nuisance afforded by the tube can be alleviated by creating a permanent drainage stoma. To do this the skin is sewn to the parietal pleura at the time the rib is resected and thus the drainage track is lined throughout with skin and does not require a tube to keep it open

CHAPTER 8

Technique of Pneumonectomy

T HOLMES SELLORS

COMPLETE REMOVAL of a lung as an acknowledged and accredited operation has made a late appearance in the history of surgery and only in the course of the last ten or twelve years have the difficulties that stood in the way of its performance been successfully overcome. Chief amongst these obstacles has been the ever present problem of the open pneumothorax at operation The gradual solution of this problem has been made possible by the development of modern anaesthetic methods which now allow the surgeon to work deliberately and unhurriedly Advances in technique have accrued from increased experience and these with corresponding advances in chemotherapy and blood transfusion have now made the operation of pneumonectomy a routine and safe procedure At the present time dissection pneumonectomy with individual ligation of the great vessels and bronchus is the only form of total lung excision that is countenanced The earlier snare or tourniquet form of pneumonectomy was at best an imperfect operation and one quite unsuited to the treatment of malignant disease

PRELIMINARY CONSIDERATIONS

INDICATIONS

Tumours

Carcinoma of Lung The most frequent indication for pneumonectomy at the present time is to be found in operable cases of carcinoma of the lung (Fig 118) Here pneumonectomy must take a radical form so as to include the regional lymph glands and variations or modifications which aim at improved technical clearances of these areas can be devised as the occasion demands

Bronchial Adenoma A more benign form of tumour the so-called bronchial adenoma, may also require pneumonectomy though, if localised it frequently permits of lobectomy being performed If there is any suspicion that this form of tumour has undergone malignant change then the more extensive operation is indicated

Pulmonary Suppuration

The next group of conditions can be classified under the heading of pulmonary suppuration The indications cannot be rigidly defined as some cases will respond to drainage and others to segmental resection or lobectomy Examples in which pneumonectomy may be required are unilateral cases of spreading suppurative

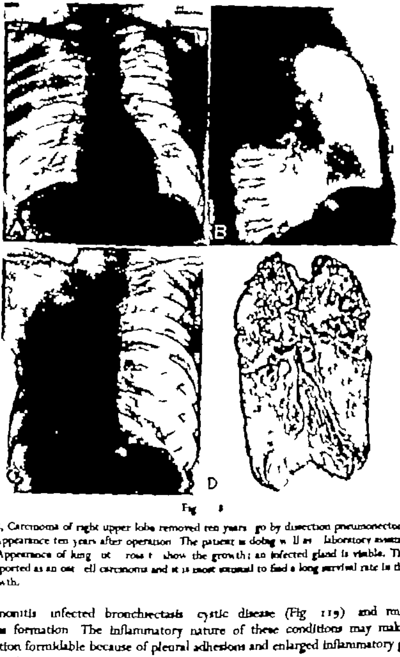
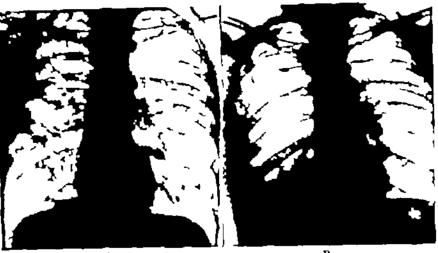


Fig [illegible]

A, *B*, Carcinoma of right upper lobe removed ten years ago by dissection pneumonectomy
C, Appearance ten years after operation The patient is doing well as laboratory assistant.
D Appearance of lung cut across to show the growth; an infected gland is visible. This case was reported as an oat cell carcinoma and it is most unusual to find a long survival rate in this type of growth.

pneumonitis infected bronchiectasis cystic disease (Fig 119) and multiple abscess formation The inflammatory nature of these conditions may make the operation formidable because of pleural adhesions and enlarged inflammatory glands at the hilum

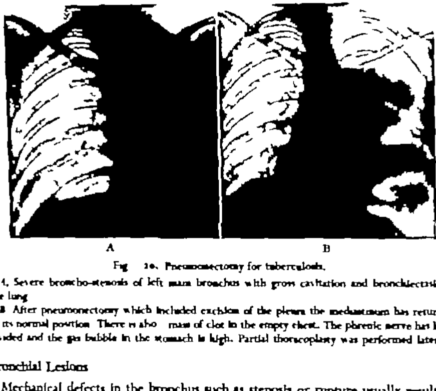


A B

Fig. 9.

A, Cystic disease of the right lung. In this case there was an abnormal pulmonary artery. There was severe toxaemia and purulent sputum measured 8 ounces daily.

B, After pneumonectomy the dead space remained clear and only obliterated after two years. The patient died five years later from pulmonary tuberculosis in the remaining lung.



A B

Fig. 10. Pneumonectomy for tuberculosis.

A, Severe broncho-stenosis of left main bronchus with gross cavitation and bronchiectasis of the lung.

B, After pneumonectomy which included excision of the pleura the mediastinum has returned to its normal position. There is also mass of clot in the empty chest. The phrenic nerve has been divided and the gas bubble in the stomach is high. Partial thoracoplasty was performed later.

Bronchial Lesions

Mechanical defects in the bronchus such as stenosis or rupture usually result in atelectasis with later infection, though in the early stages gross obstructive emphysema may be encountered. Here again pneumonectomy may be required if the affected bronchus is the main stem and not a lobar branch.

veins has been invaded by growth which is spreading into the auricular wall In spite of this formidable list of contra-indications there is still a wide scope for courageous and successful surgical interference in this distressing form of malignant disease (see accompanying table)

Pneumonectomy Analysis of Author Series

	NUMBER	PER CENT
Carcinoma		
Operations performed	76	
Died within 6 months after operation (without leaving hospital)	29	16 5
Died between 6 months and 2 years after operation	68	39
Still alive 6 months to 2 y ars after operation	28	15 9
Have survived beyond 2 years	5	28 8
(Of these 37 have lived more than 5 years, the longest survival period being o years)		
Adenoma		
Operations performed	8	
Deaths	1	2 5
Tuberculosis		
Operations performed	2	
Deaths.	5	25 0
Bronchiectasis and Suppurative Conditions		
Operations performed	67	
Deaths.		5

PREPARATION OF THE PATIENT

It is important that deliberate pneumonectomy should not be undertaken without having prepared the patient with every possible precaution. A preliminary course of breathing exercises should be especially directed towards the healthy side and the patient should be trained to cough and to become aware of the possibilities of voluntarily controlling his respiratory function. At least two to three weeks should be spent on these lines, the patient taking as much general exercise as he feels inclined The diet should be unrestricted and the use of vitamins particularly ascorbic acid, is a routine essential If there is any infection in the lung, postural drainage should be carried out for several periods of half to one hour three or four times a day elderly patients may find this difficult at the start but if purulent secretions can be drained the state of the lung will be improved by the time of operation Penicillin inhalations can also be used to reduce the infectivity of sputum, and it is customary to initiate a full course of parenteral penicillin starting three to fi e days before operation

Needless to say during this period of preparation other organs and systems will ha e been examined and assessed so as to avoid such untoward occurrences as retention of urine after operation Teeth and nasal sinuses require attention particularly if pneumonectomy is being undertaken for an infective condition In the case of patients with bronchial carcinoma this toilet should not be stressed unduly

POSTURE OF THE PATIENT

There are three standard approaches for pneumonectomy:

1 The anterior approach with the patient prone (Fig 122)

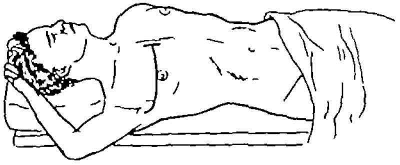


Fig 122 An incision for pneumonectomy by the anterior approach

2 The lateral approach the patient lying on the good side (Fig 123)

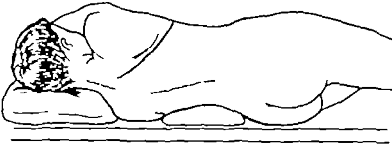


Fig 123 Position and incision for postero-lateral thoracotomy

3 The posterior approach the patient lying on the face (Fig 124)

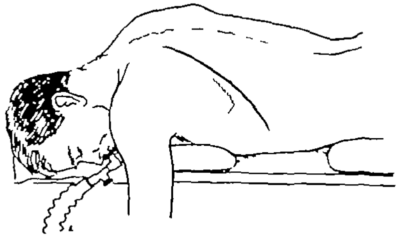


Fig 124 Position of patient and incision in posterior thoracotomy—face-down position. (After Parry-Brown.)

In general the lateral position is the one most commonly favoured though I have consistently used the posterior approach for the past six or seven years The advantages of the anterior and posterior approaches are that the mediastinum is not displaced and the anaesthetist s control of respiration is more easily established. The danger from displacement of secretions into the opposite lung is not serious as it is in the case of the lateral approach if bronchus blocking has not been successfully carried out There is little doubt that the lateral position is the most comfortable for the surgical team but we have found that the posterior approach has many advantages in that the hilar structures are much closer to the chest wall opening and visibility is improved.

ANAESTHESIA

Technical and Physiological Problems

The recent developments in anaesthesia have largely contributed to the success of intrathoracic surgery The technical problems provided by an open pneumothorax have had to be overcome and a number of difficulties have had to be solved so that the surgeon can operate carefully and deliberately with the maximum safety There are three essentials that have to be considered

1 Adequate oxygenation in the presence of an open pneumothorax.
2 The prevention of contamination of healthy lung by blood or secretions
3 The maintenance of stability of the mediastinum during operation.

The difficulties are seen at their worst in the case of pneumonectomy for wet bronchiectasis with the patient lying on the healthy side In spite of preliminary postural drainage pus and secretions are bound to be squeezed from the bronchiectatic lung, and these will tend to gravitate into the healthy lung and prevent, initially its ventilation and later lead to atelectasis and infection Bronchus blocking and suction with anaesthetic agents which include a high concentration of oxygen have to be used to overcome most of the problems and controlled or assisted respiration helps to maintain a steady mediastinum

As has been said, the problems of anaesthesia are largely bound up with the posture of the patient at operation. If it were technically possible to have the patient slung up so that the surgeon could operate from underneath—in other words with the good side uppermost—there would be practically no problem The accepted lateral position, which is the reverse of this provides the maximum of difficulties to the anaesthetist A point which is rarely made is the amount of mediastinal displacement arising from the use of the lateral position. We have measured this carefully after pneumonectomy and have found it to average between 650 and 850 c.c. in the case of middle-aged men this volume of air has to be withdrawn at the end of operation when the patient is turned from his side on to his back to achieve the same manometric pressure

The face-down position (Fig 125) was adopted largely to overcome the obvious disadvantages of the lateral position. The bronchial drainage is dependent and the healthy lung safe from contamination the mediastinum remains central and the necessity for controlled respiration not so absolute though it is usually used during some part of the operation

Technique

Modifications and variations are endless but an example of our present technique for an average adult may be briefly given.

Preliminary postural drainage just before the patient is brought to the operating theatre is essential and can be assisted by deliberate coughing efforts. An hour or more before operation a preliminary sedative is given (omnopon 10 to 12 mg. [$\frac{1}{6}$ to $\frac{1}{5}$ grain] hyoscine 0.4 mg. [1/150 grain]). In the theatre an intravenous drip is set up and through this anaesthesia is induced by pentothal (0.5 gm.) and followed by a curare preparation (tubarine 10 to 12 mg.). This latter allows sufficient relaxation for intratracheal intubation with a wide-bore cuffed Magill tube. If there is any free secretion the anaesthetist usually removes this by bronchoscopic suction as a preliminary measure. The wide intratracheal tube allows enough room for passage

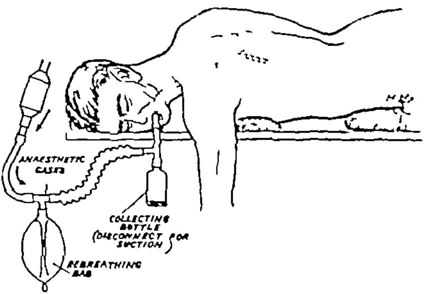


Fig. 25. Arrangement of anaesthetic apparatus. The tube in which secretions may collect can be disconnected and used for suction. The position shows how the bronchial drainage is maintained in the face-down position.

of a suction catheter should secretions be too thick or viscid to gravitate from the bronchi and also affords free access for anaesthetic gases.

If diathermy is used, ether and cyclopropane are excluded and gas oxygen administered. In this event, further small doses of pentothal and curare may be given during the course of the operation to maintain an adequate depth of anaesthesia. During an average operation lasting one and one half to two hours the total dosage of pentothal does not exceed 1 gm.; of tubarine, 15 to 20 mg.

Recently the amount of anaesthetic agents used after induction has been greatly reduced by using a paravertebral local anaesthetic block; this consists of 7 c.c. of 0.5 per cent procaine solution with adrenaline into each of the thoracic interspaces. Amethocaine gives a more prolonged effect if this is needed. This block is rapidly introduced by the surgeon after the patient has been placed in position.

Post-anaesthetic Care

At the end of the operation the anaesthetist removes the intratracheal tube and if there is any suggestion of bronchial or tracheal secretions the patient is rolled on to the bed keeping the operation side undermost Bronchoscopic toilet then is carried out by the anaesthetist to make sure that no foreign matter remains in the air passages It should be added that the anaesthetist can perform bronchoscopy during the operation without too much difficulty and without moving the patient from the face-down position

The intravenous drip is usually started with normal saline which gives place to blood when the operation is well under way In pneumonectomy the administration of blood must be slow to avoid overloading of the heart and in general 2 pints are *all that will be required Three pints is the maximum that should be given unless* there has been any severe loss of blood

OPERATIVE TECHNIQUE

INCISION

The actual incision in the case of the lateral and posterior postures is approximately the same and consists in a long (10-inch) incision starting in the paravertebral region and extending obliquely downwards and forwards to the midaxillary region just below the angle of the scapula (Fig 126)

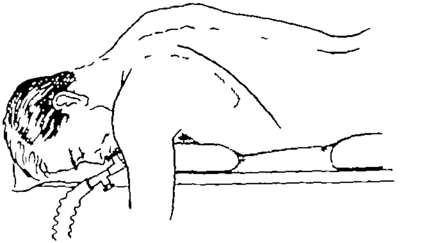


Fig 126 Position of the patient and line of the incision in the operation of pneumonectomy in the face-down position.

The muscle layers that are incised are in two planes superficially there is the lower end of the trapezius and more laterally the latissimus dorsi muscle In the latter several bleeding points associated with nerves are encountered In the deeper plane there is the lower part of the rhomboid muscle and in front of the angle of the scapula the massive sheet of the serratus magnus is encountered the fibres of which can be split downwards and forwards The nerve supply and blood vessels in this muscle lie on its superficial aspect When these two muscle planes have been divided the ribs are exposed (Fig 127)

The rib chosen for entry into the chest depends to some extent on the position of

the growth In other word an upper lobe ma is best approached by a 5th rib incision and a lower lobe by a 6th or 7th The rib is resected subperiosteally for the

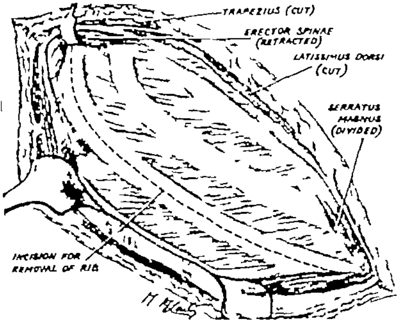


Fig 127 Exposure of rib surfaces after division of the superficial muscles.

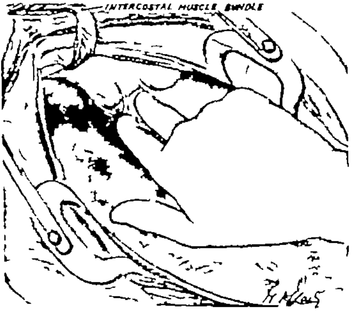


Fig 128 Opening of the chest following resection of rib exposing the posterior aspect of the lung root.

full length of the incision and when complete haemostasis has been obtained the pleural cavity is entered

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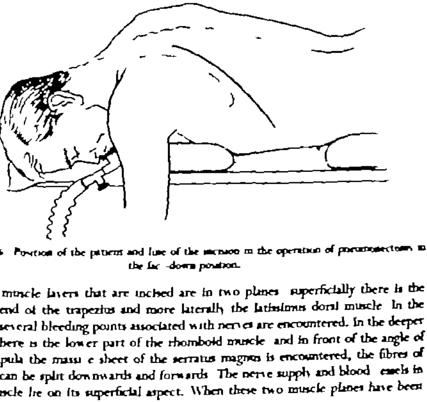

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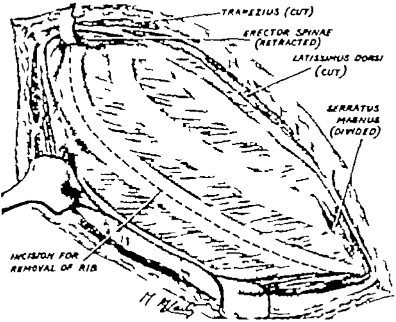


Fig 17 Exposure of rib surfaces after division of the superficial muscles.

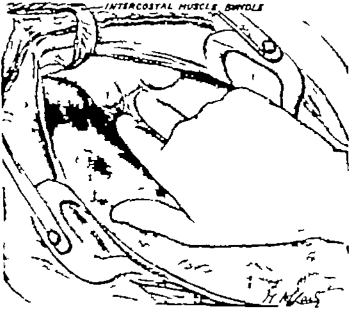


Fig 18 Opening of the chest following resection of rib exposing the posterior aspect of the lung root.

full length of the incision and when complete haemostasis has been obtained the pleural cavity is entered

During the exploratory stage if a non-explosive anaesthetic is used the incision can be made with diathermy and bleeding points are sealed by coagulation The advantage of this is the saving of time and prevention of blood loss Once the chest has been opened (Fig 118) a mechanical retractor or rib spreader is placed in the incision and forcibly opened until a space about 4 or 5 inches wide is obtained. If more room is required division of the back end of a rib above or below can be considered

FREEING OF LUNG

The first procedure in the case of a growth is to determine its operability If there are only a few or slight adhesions and if there is no thickening or enlargement of glands at the hilum pneumonectomy is straightforward, but the decision becomes

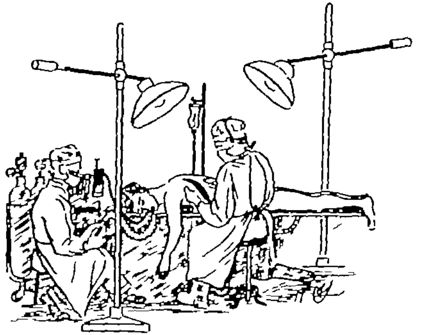


Fig 9 Arrangement of staff and fixtures at thoracotomy Note continuous saline or blood-drip and the use of two movable lamps sources of illumination Towels, assistants, and other minutiae are not shown.

more difficult when the growth is firmly adherent to or eroding, the chest wall and if there are enlarged and palpable glands at the lung root. The decision to excise may possibly have to be postponed until further dissection is made. With an inflammatory condition the probability is that the *hilum will show a matted mass* of enlarged and vascular glands and that the adhesions, in part at any rate may be very dense against the pleura

Mural Attachments

The decision having been made that the lung can be removed, the first step is to ensure that it is freed from adhesions, and the division of these can be effected in some cases by blunt dissection or gentle stripping, while in others ligation is

obviously required When adhesions are so dense and vascular that there is no plane of cleavage it is wiser to divide the parietal pleura and strip the adherent area away in the plane of the endothoracic fascia This should certainly be done for obvious growth but it leaves a raw and often bleeding area from which haemorrhage has to be controlled with diathermy coagulation or such an agent as fibrin foam The division of extensive vascular adhesions is often associated with a considerable degree of shock and in infective cases is certainly the most formidable part of the operation Areas to be watched carefully for unexpected bleeding are at the posterior apex of the lung and anteriorly if the lung has become adherent to

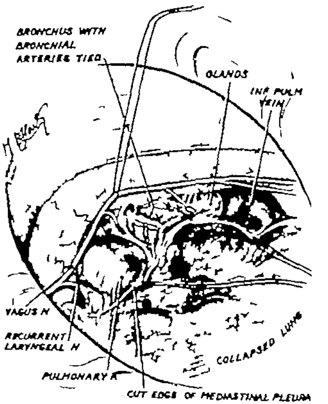


Fig 3 Division of mediastinal pleura and superficial dissection of the bronchus and great vessels.

pericardial fat When extensive extrapleural stripping is used the plane of dissection must be carefully watched over the posterior mediastinum particularly in the region of the oesophagus

HILAR REGION

With the lung freed from its mural attachments the actual anatomical structures of the hilum require attention One of the first procedures is to identify the pulmonary ligament as it runs downwards from the hilum to the costophrenic angle This double fold of pleura contains one small artery at its lower part and another vessel close to the inferior pulmonary vein Consequently this structure should be secured and ligated before division The pleura round the lung root is then incised

starting at the upper and anterior level with the lateral approach, and posteriorly if the patient is face downwards

In the hilum are four separate structures that have to be secured the main bronchus, the pulmonary artery and the upper and lower pulmonary veins. It is customary to secure the artery before the veins but in actual practice no ill effect is detected when the order is reversed

Isolation of and Securing the Bronchus

In the posterior approach it is convenient to isolate and secure the bronchus first of all This has the advantage that secretions or blood will be retained in the lung and not be displaced by manipulation On the posterior aspect the bronchus presents its soft posterior wall bounded by the two sharper margins of the cartilaginous

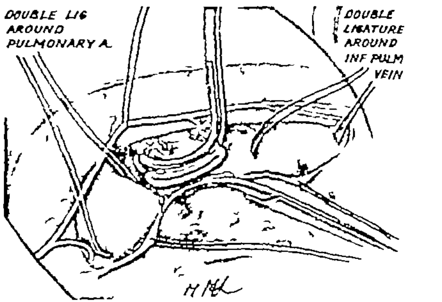


Fig 3 Division of the bronchus between clamps with ligatures encircling pulmonary artery and inferior pulmonary vein

rings One or two bronchial arteries are usually apparent and they should be carefully secured as they are friable and easily damaged structures Careful and meticulous dissection on the upper and lower borders of the bronchus holding close to its cartilage walls finally allows an instrument or even finger to be passed round this structure A special clamp is then placed round the bronchus close to the bifurcation of the trachea A distal clamp is also applied and the bronchus divided between the clamps (Fig 3) The cut ends are wiped clean with a swab and dusted with penicillin-sulphathiazole powder It is sometimes safer to divide the bronchus at a convenient point and to defer the final and more proximal point of section until the rest of the hilum has been secured

At this point the technical principles involved in hilar dissection can be discussed. The superficial aspect is usually well defined and visible after careful removal of fascia, and the lateral borders can be cleared by gentle blunt dissection but the

deep quarter or third of every tube i an area where the utmost care should be taken Inflammatory adhesions bind essels so closely together that their plane of separation is not necessarily obvious to the naked eye vessels can be drawn into folds or pockets which can be perforated if a sharp instrument is used Blunt curved forceps worked along the line of the vessels help the dissection but the safest and the most satis factory instrument is the tip of a finger working and rolling on the deep surface against the thumb In this way the actual fold or outline of the vessel may be felt, and by gently easing connective ti sues from the walls the vessel can be encircled

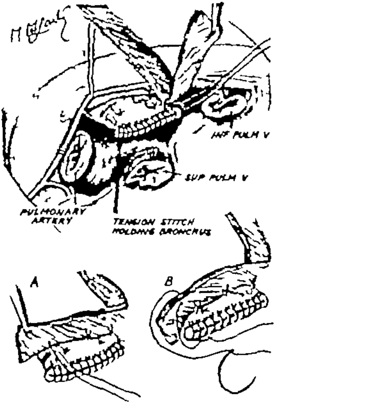


Fig 32 Appearance of the long hilum after ligation of the main vessels. Inset show method of closing the bronchus using pedicle intercostal muscle graft t cover the suture line The bronchus should be divided practically flush with the carina and in this case would hav had to be divided at higher level than show and then pulled dow beyond the rch of the aorta for suturing

The essel or bronchus to be isolated must be sufficiently long for the application of clamp or ligatures so that these do not slip when the structure is divided A third of an inch is the absolute minimum and in general one should not be content with less than half an inch of clearly defined structure Moreo er when the structure is isolated very fine dissection to remove all adventitious tissue should be made as its inclusion in a ligature might possibly lead to slipping later

Isolation and Ligation of the Great Vessels

The order of taking the great vessels should as a rule follow the practice of taking the artery first and the eins later but as has been said it does not appear to make

any difference which vessel is taken first, and if the hilar dissection is difficult it may be advantageous to divide the most easily accessible structure and thus provide additional exposure of the other vessels (See Fig 132)

The left pulmonary artery can always be divided at its main trunk where it is a wide and comparatively long structure as it appears from under the aortic arch. On the right side however preliminary section of the artery to the upper lobe will be

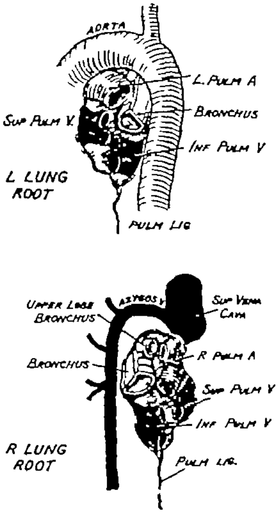


Fig 133 Diagrammatic view of the relations at the lung roots.

more convenient than ligation of the main trunk this is then followed by ligation of the big branch to the middle and upper lobes

The inferior pulmonary vein can nearly always be isolated as one wide trunk as it emerges from the pericardium, and if this is followed towards the lung the two branches into which it divides can readily be divided separately if circumstances require

The superior pulmonary vein lies in almost direct contact with the superior and

anterior aspect of the inferior vein and just in front of and below the artery It can usually be dealt with as one trunk; but of all the hilar structures it is often the most stumpy and short so that division of the separate branches to the upper lobe and to the middle lobe may be desirable Just behind and above the superior vein the pericardium may be pulled forward and nicked a circumstance of little importance in non infective cases If a small opening is accidentally created it can be sutured but if extensive it is best left open

Ligation of Small Vessels and Nerves

In addition to the main structures that have been described there are several nerves and small vessels that require ligation If they are accidentally divided before being secured they tend to retract and cause troublesome oozing At the upper part of the hilum branches to the pulmonary plexus from vagus and sympathetic nerves may be seen entering posteriorly there is a branch coming from the vagus nerve into the back of the hilum and a corresponding twig from the phrenic at the level of the superior pulmonary vein Inferiorly there is as has already been mentioned a small constant vessel lying against the lowest margin of the inferior vein Pathological changes at the hilum naturally induce distortion and additional vascular channels which require attention as circumstance demands Oozing is usually encountered in the neighbourhood of glands and when the bronchus is being dissected towards the carina

GLANDS

In carcinoma of the lung the glandular field requires special attention On the left in the upper part is a constant gland—gland of the ductus arteriosus—and on the right there are two paratracheal glands lying against the trachea well above the hilum Deeper placed glands lie in the bifurcation of the trachea and have to be carefully removed, and on the right there is usually a large gland lying between the bronchus stem and oesophagus Inferiorly a small gland may be seen at the bottom of the pulmonary ligament, with a more definite oval one just below the inferior vein These are the glands commonly encountered at the level of dissection the ordinary bronchial groups being included in the excised lung

INTRAPERICARDIAL LIGATION OF VESSELS

Some variations in technique may become necessary in the course of removing a pulmonary carcinoma the most common being when the growth is invading one of the great essels and possibly pericardium Here a deliberate incision can be made into the pericardium and extended up to the hilum so that the vessels are secured intrapericardially This is not difficult though in each case a reflected fold of the pericardium has to be di ided before the vessel is encircled In such a case the pericardium is left freely open ensuring, in the case of a medium-sized deficiency free drainage If especially on the left the pericardium is extensively removed, the heart easily becomes displaced from its normal position into the pleural cavity and may cause distress On one occasion in our experience the size of the pericardial gap was such that the heart came through the opening and was strangulated Intrapericardial dissection has many advantages and does not add greatly to the shock of the operation though convalescence is not so smooth and there is excessive post operati e effusion

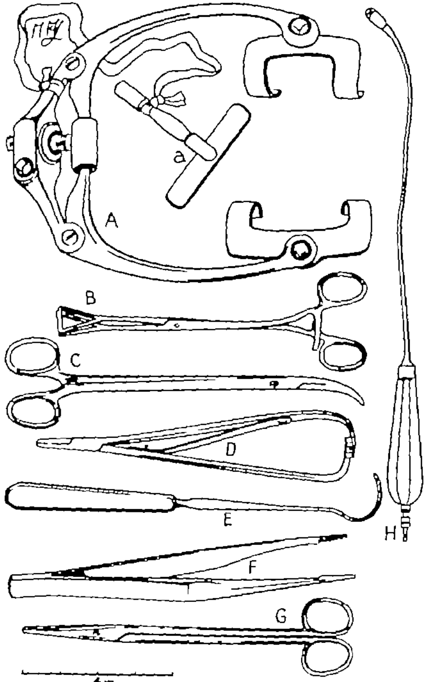


Fig 34. Some instruments used in intrathoracic work *A* Rib retractor or spreader Author modification of de Quervain pattern *B* Duval long holding forceps. *C* Long curved artery forceps or haemostat—Roberts or Tudor Edwards pattern. *D* Needle holder—Stille pattern. *E*, Aneurysm needle—used for passing ligatures This instrument is made in several shapes and angles. *F* Dissecting forceps—fine points, square end G Long scissors—usually curved *H* Malleable light for illuminating dark corners

VARIATIONS TO ADD TO THE EXTENT OF THE PROCEDURE

If phrenic and vagus nerves are involved in the growth they should be resected without any attempt to preserve them The loss of the phrenic nerve is actually an advantage in that the diaphragm will be raised after operation and there would appear to be no ill effects from the division of one vagus though naturally if the left one is divided above the level of the aortic arch there will be paralysis of the left vocal cord The azygos vein can be divided in order to improve the lower tracheal exposure on the right side and on two occasions I have resected a small area of aortic wall the deficiency being repaired by suture Large sections of chest wall including several ribs can be removed where the growth is invading that area and the diaphragm can also be excised in part if the operability of the growth is determined by adhesion to that structure A planned block dissection involving clearance of the mediastinal pleura and intrapericardial ligation of vessels constitutes a more severe operation than the standard pneumonectomy but may make the difference between a radical and palliative operation

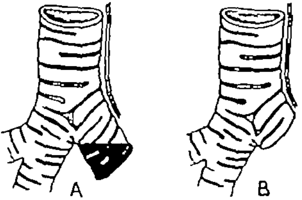


Fig 135 The correct point of division for bronchus is show (B) If long stump is left, secretions and possible infection may develop in the blind end (A)

CLOSURE OF THE BRONCHUS

The closing of the bronchus deserves separate discussion since maintenance of this closure is the most important feature in the post-operative phase At the start it may be said that many and diverse methods have been, and are being used, but in general three principles are followed

1 That the divided bronchus stump should be carefully and accurately closed by suture so that the walls are approximated and the suture line is air tight.
2 That its point of division should be close to the bifurcation so that a stump which might later become stagnant and infected is not left behind (Fig 135)
3 That the line of suture should be reinforced by a covering of living tissue which will act as a graft if and when the closing sutures might be expected to be cut out (in ten to sixteen days)

Our practice is to remove the control clamp from the bronchus and with the use of a sucker to insure that there is no pus or fragment of growth in the opening If the bronchus has not been divided close enough to the bifurcation, the walls are

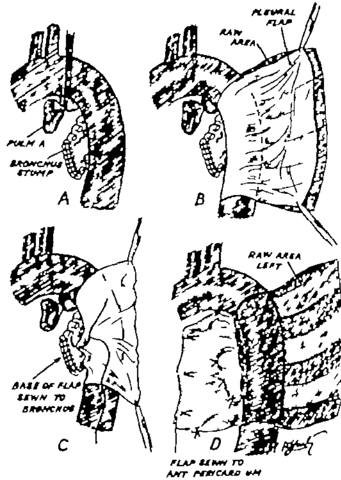


Fig 36 Covering of the bronchus stump with a pleural flap cut from the posterior chest wall The flap is held in position by sutures placed close to the point of division of the bronchus.

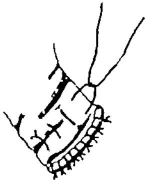


Fig 37 Closure of bronchus using vertical mattress sutures.

trimmed away until closure can be made without leaving a bronchus stump The opening is then dusted with penicillin powder and a number (eight to twelve) of sutures of a non-absorbable variety (60 linen thread) are inserted through the edges

including about 2 mm of bronchus wall and lying 1 mm apart In some instances a pleural flap may be cut from the paravertebral gutter and hinged forwards and then lightly sutured over the stump (Fig 136) On nearly all occasions we use a

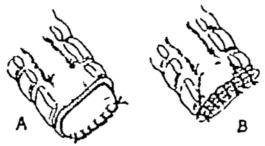


Fig 138 Closure of bronchus by excision of cartilage rings leaving mucous membrane cuff which is invaginated after being sutured. The more rigid bronchial walls are sewn together over this.

pedicled intercostal muscle bundle as originally suggested by Brock This is cut at the time of the incision through the chest wall using half the thickness of the lower intercostal bundle in the incision This is turned back and kept away from retractors until it is required for use It is then brought down and placed with three fine

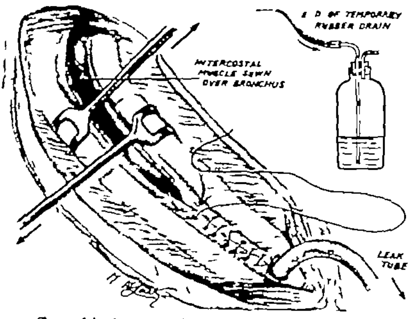


Fig 139 Closure of the chest using small retractors *to approximate ribs. In the front part of* the wound leak tube leading to water seal drainage bottle is shown. This serves for evacuation of air and stabilisation of pressures while the chest is being closed. Posteriorly the intercostal muscle graft is seen leading down to the bronchus stump

sutures on each side of the bronchus and with one or two holding on to the actual line of suture (Fig 132) This mushroom of living muscle affords a firm barrier both mechanically and vitally against any possible bronchial fistula. Between the stitches to the bronchus several penicillin tablets (8 000 units each) are inserted

Approximation of pleural or fascial tags o er the region of the stump reinforces the muscle graft. Other methods of closure depend for their efficiency on the type of suture material some form of covering, or invagination of mucosa after removal of cartilage rings (see Figs 137 and 138)

CLOSURE OF THE CHEST

The toilet of the anterior of the chest is made after ensuring complete haemostasis, and by increasing the endotracheal pressure the anaesthetist can confirm that the bronchus is completely closed Five hundred thousand units of penicillin are left in the pleural cavity and accurate haemostasis is confirmed. The chest is closed by a continuous suture between the intercostal muscles over the divided rib bed (Fig 139) It is of little importance whether or not the parietal pleura is closely co-apted and by using a rib approximator or hooked retractors the strain is taken from the continuous suture We do not find it necessary to use pericostal sutures unless the circumstances are exceptional The pleural cavity is completely closed by this continuous stitch possibly with one or two supporting sutures and the muscle layers are brought together before closing the skin. At the completion of operation the pressures inside the chest are adjusted with a pneumothorax apparatus or by using a temporary leak tube during closure lea ing them just below atmospheric pressure with the patient lying prone or on the face

Bronchoscopic toilet is usually carried out and a single layer of gauze dressing is applied to the wound and held in place by two lengths of elastoplast It is important to a oid bulky dressings from the point of view of after treatment No drainage tube is used

AFTER TREATMENT

The patient is returned to bed flat with continuous oxygen given through a B L B or similar mask and with the transfusion drip still in place

On recovering consciousness the patient is gradually gi en pillows according to the general condition and by the end of four or six hours can be in a sitting position. In this posture he can cough more easily and has the least embarrassment in respiration The cough is painful but must be encouraged at all costs to keep the remaining lung free from secretions and away from the danger of atelectasis or infection Morphine may be gi en in doses that do not interfere with the cough reflex but which will relieve the worst of the pain The patient should drink freely as there is little or no tendency to vomiting Any undue restlessness should be carefully observed in case it betokens cerebral anoxia and any laboured or distressed breathing with obvious moist sounds indicates urgent bronchoscopy if the patient s cough reflex is not effecti e

On the following day a radiograph is taken and if there is any marked collection of fluid in the chest this is aspirated.

It is the custom of some surgeons to use a closed water-seal drain for twenty-four to forty-eight hours after operation for the removal of this fluid and blood, though in our experience the xtra mobility gained by the absence of a tube compensates for the discomfort of the aspiration that is required

The pressures in the chest after any aspiration should be adjusted to atmospheric level and should be checked by the position of the mediastinum and by the radio-

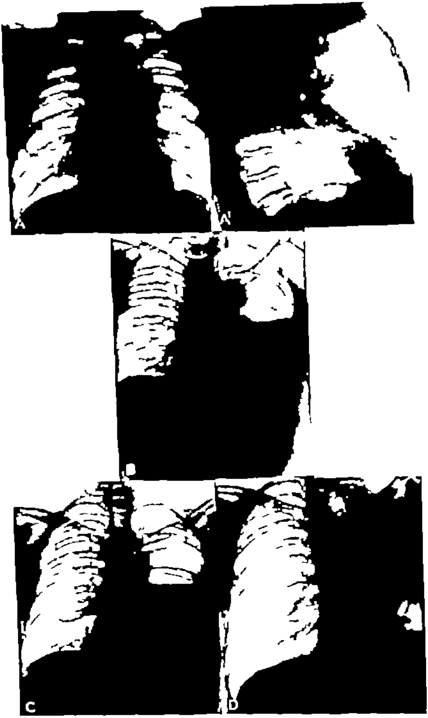


Fig. 40. Carcinoma of left lung discovered on mass radiography and treated by pneumonectomy. The patient had no symptoms.

A, A'. Antero-posterior and lateral films before operation.

B, Appearance twenty-four hours after operation showing subcutaneous emphysema and fluid collection above the raised diaphragm.

C, Appearance three days later before aspiration of the chest.

D, Eight weeks later the mediastinum has been pulled over and there is a heavy deposit of fibrin in the dead space. Note the height of the diaphragm. The patient had returned to work.

logical appearance An average case will require three or four aspirations over seven to twelve days, the fluid on each occasion being examined bacteriologically The fluid is invariably blood-stained and a deposit of fibrin of varying extent appears in the costophrenic angles obliterating the bottom of the space One hundred thousand units of penicillin injected at the end of each aspiration help to maintain the sterility of the fluid Too rapid accumulation of fluid may lead to pressure which should be immediately relieved by removal of air or fluid.

According to the condition of the patient he can be allowed out of bed sometimes within two or three days of the operation and be permitted from that point to find his feet, so that within ten to fourteen days he may be walking round the ward and wearing ordinary clothes

PHYSIOTHERAPY

Physiotherapy is of great importance to be used as soon as the patient has properly recovered consciousness He is encouraged to breathe with his remaining lung and to cough forcefully at regular intervals This question of coughing is probably the most important feature of the after treatment, since the inclination of the patient will be to remain still on account of discomfort. Firm physical support to the back and front of the operated side with active moral encouragement enables the patient to cough adequately in most cases and it should be a rule not to give depressant doses of morphine until an effective cough has been obtained On the following day movements of the arm and shoulder are started and the posture of the patient is carefully checked It is easy for a patient to lie slumped in bed and rapidly to develop a kyphosis and scoliosis if left to his own devices. Active expansion exercises on both sides are aimed at and the patient will remain under the care of the physiotherapist until he returns home In general the patient should be capable of returning home in three and one-half to four weeks from the date of operation, and naturally during the post-operative phase the blood count and general health will be watched

COMPLICATIONS

The complications can broadly be divided into those which may occur during the first two or three days and those which are seen after an interval. In the first group there are the obvious surgical risks such as shock, haemorrhage, and in the case of thoracic surgery too great loss of ventilating tissue with consequent anoxia heart failure has been encountered in toxic subjects and may be associated with acute oedema of the remaining lung Air embolism is a rare occurrence but has been encountered when a ligature has slipped from a great vein or when one of these structures has been torn A leak of air or excessive bleeding (Fig 120 *B*) into the empty chest space can lead to pressure effects in the early post-operative stage but the chief complication to be feared is aspiration of foreign material into the good lung with consequent collapse or infection Systemic penicillin has proved of great value in combating this danger and if bronchoscopy is carried out in cases where the lung is obviously wet this complication need not lead to disaster

BRONCHIAL FISTULA AND EMPYEMA

The principal danger lies however in pleural infection which is usually associated with, or caused by a bronchial fistula This occurs any time after the tenth day and

is recognised by the expectoration of blood-stained fluid in bulk This can occur even with an opening the ize of a pin in the bronchus stump Some fistulae close spontaneously but the majority persist and are followed by infection of the dead space beyond In the early stages repeated aspiration and penicillin may prevent the condition from becoming serious but if the infection persists drainage of the dead space will have to be undertaken and at a later date a thoracoplasty will be required to obliterate the ca ity and close the fistula In the early days of pneumonectomy this was a frequent and grave complication and though greatly reduced it still looms large among post-operative risks *A soundly healed bronchus* involves the patient in only a short period of convalescence but if a fistula develops it may take months before the patient is out of the hands of the surgeon

OBLITERATION OF THE DEAD SPACE

The empty hemithorax produced after pneumonectomy affords less of a problem than might be expected If it remains uninfected a series of aspirations over the first

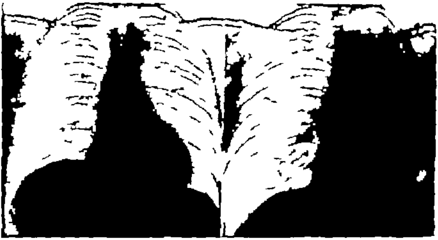
A B

Fig 4 Radiographs of child suffering from advanced bronchiectasis of both left lobes—before (A) and after (B) pneumonectomy The child is now symptomless and ble to play all games.

ten days or so removes blood-stained serum that has accumulated and the pressures are adjusted to about atmospheric level An appreciable deposit of fibrin can be observed collecting on the chest wall and particularly over the diaphragm at this time and this deposit slowly thickens at such time as the mediastinum is drawn into the empty side A small collection of fluid is invariably present but should not increase in volume to any extent and does not require aspiration Sometimes within six months the fibrin coupled with displacement of mediastinum and to less ex tent the chest wall obliterates the space but in other patients a fluid level and small air-pocket can be observed for a year or more The gross mediastinal dis placement may cause slight inconvenience to swallowing or breathing but is usually compensated for without any ill effects Theoretically an upper thoracoplasty would remedy the distortion but we have never found it necessary to perform this operation except in tuberculosis or where the pleura has become infected In this latter case a thoracoplasty is needed to obliterate the dead space and to close the bronchial fistula if this is present

Functional capacity at an interval after pneumonectomy is excellent if the remain

ing lung is sound A child can play games a youth finds limitation only in the most strenuous forms of exercise a healthy adult can easily manage golf in addition to



A B

Fig 142

A, Radiograph of early carcinoma of the lung at the left of the aortic arch. The only symptom was haemoptysis—the growth had invaded the thickness of the left main pulmonary artery

B, Appearance five years after pneumonectomy The patient did full work as a dental surgeon for eight years when he died from an unknown cause

Fig. 143 Radiographs of extensive carcinoma of the right upper lobe An abscess has formed due to breakdown of the growth. Pneumonectomy was satisfactorily performed and the patient remains well two and one-half years later

ordinary work, and the more elderly whose capacity for active exercise would in any case be reduced finds that the tempo of his life has not been seriously affected

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CHAPTER 9

Surgical Treatment of Pulmonary Tuberculosis

PRICE THOMAS

OPERATIONS for pulmonary tuberculosis are directed towards the closure of the tuberculous cavity A tuberculous cavity persists because air is trapped in the cavity left by the rupture of the tuberculous abscess into the bronchial tree. The mechanism producing this state of affairs depends on the invariable presence of a tuberculous bronchitis in the bronchi draining the cavity The bronchitis leads to serious narrowing of the lumen of the bronchus, so that although during inspiration when the lumina and length of all the bronchi enlarge the bronchi draining the cavity are patent and air is drawn into the cavity during expiration, when the lumina of all the bronchi get smaller the bronchi draining the cavity which are partially stenosed close before the expiratory phase is finished thus all the air which is taken in during inspiration cannot escape, and the air is retained in the cavity at a mean positive pressure In other words the cavity is a tension cavity.

This tension within the cavity is not only a cause of persistence of the cavity but also of the disease process in the cavity wall The walls and the capillaries in the wall are subjected to this increased tension and in consequence the blood supply is poor If this tension can be eliminated the blood flow through the capillaries is increased and if the patient s resistance against his disease is good, healing or arrest of the disease ensues

It must certainly be accepted that in a relatively small percentage of cases free bronchial drainage is established. Evidence of this is given in certain cases treated by streptomycin and when this happens the pressure within the cavity returns to normal and the cavity closes by virtue of the normal retractility inherent in the lung (Fig 144)

In some of the older cases, free bronchial drainage is established without closure

of the cavity and persistence of the cavity in these cases is due to the fixation of the cavity walls to the chest wall so that the cavity cannot retract and close

In the majority of the cases however an expiratory stenosis persists and all the forms of treatment apart from those of lung resection and chemotherapy are directed towards the elimination of the positive pressure which builds up in the cavity as a result of this expiratory stenosis

The principles underlying bed rest are the same as those underlying thoracoplasty except that in bed rest passive relaxation and in thoracoplasty active relaxation are used

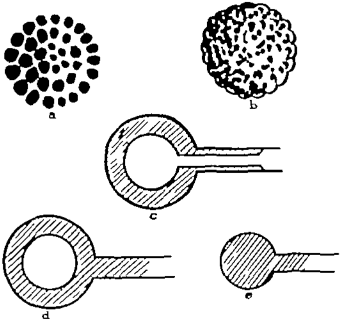


Fig 44. Drawings illustrating cavity formation, persistence and closure A conglomeration of tubercles which in *b* have coalesced to form an abscess. In the abscess has ruptured into the bronchus which is seat of tuberculous bronchitis which is producing narrowing of the lumen *d* The bronchus occluded during the last phase of expiration and air trapped in the cavity *e*, The result of bronchial occlusion which has persisted through the whole respiratory phase that is, absorption of the contained air and closure of the cavity

During bed rest, the patient s oxygen demands are considerably decreased and in consequence the depth of the respiratory excursion of the chest wall is decreased In this way the inspiratory increase in the lumina of the bronchi is limited Where cavity closure occurs as a result of bed rest the partial expiratory stenosis is severe enough to maintain a stenosis of the bronchi draining the cavity during the whole of the modified inspiratory phase In this way further quantities of air are prevented from entering the ca ity the air already in the cavity is slowly absorbed, the tension decreases the ca ity gets smaller and at the same time the blood supply to the cavity wall improves and the local defense mechanism of the patient is unhampered.

The operations for pulmonary tuberculosis may be classified under three main headings

I Operations Employing Relaxation Procedures

Methods employing relaxation are

1 *Operations on the Phrenic Nerve* producing diaphragmatic paralysis
2 *Scalenectomy* which is used in conjunction with diaphragmatic paralysis This eliminates the inspiratory elevation of the first rib and decreases to a slight extent the volume of the hemithorax
3 *Multiple Intercostal Neurectomy* This operation only produces a minor degree of relaxation its role being in the main passive When it is used in conjunction with scalenectomy and diaphragmatic paralysis the whole hemithorax remains practically immobile during quiet respiration In this way the inspiratory pull on the draining bronchi is eliminated and in favourable cases, when the functional stenosis is maintained during the whole respiratory phase the cavity closes
4 *Extrapleural Artificial Pneumothorax* which reproduces as far as the apex is concerned the conditions obtaining in an intrapleural artificial pneumothorax
5 *Thoracoplasty with or without Apicolysis* Both of these operations relax the lung and the latter attempts to reproduce the condition obtaining in the former procedure

The basic factor in all these interventions is the effect of the relaxation procedure on the draining bronchi and to produce a satisfactory result the draining bronchi must be closed At first only a functional stenosis is achieved but if this is maintained sufficiently long and the patient s resistance is good, healing of the tuberculous bronchitis takes place by fibrosis and the bronchi become organically stenosed.

From the above considerations it will be appreciated that those procedures which utilise concentric relaxation should produce the best results, because such relaxation will relax the draining bronchi more certainly than a procedure that produces relaxation in one direction only A perfect artificial pneumothorax that is, one in which there are no adhesions between the lung and the chest wall and in which there are no other complications such as a broncho-stenotic lesion, will give cavity closures in 90 to 95 per cent of cases Thoracoplasty with an efficient apicolysis can be expected to give these results in 85 to 90 per cent of cases as also will extrapleural artificial pneumothorax On the contrary lateral thoracoplasty resulting from rib resection gives an expectation of cavity closure in only 30 to 60 per cent, and diaphragmatic paralysis even in carefully selected cases cannot be expected to give good results in more than 30 to 50 per cent of cases.

It must not be adduced from this that the minor interventions are useless because of the smaller expectation of cure other factors such as mortality or morbidity have to be taken into consideration as well as the magnitude of the separate interventions Nevertheless it is a cardinal error to submit a patient to a minor intervention merely because it carries with it little disturbance and small risk, when manifestly there is little expectation of a satisfactory result The treatment of each case is an individual problem and should be considered from all angles the patient s ability to withstand the projected operation, the risks entailed and last but not the least the expectation of cure or arrest resulting from the chosen intervention

II Operations Employing an Artificial Stoma

Monaldi cavity drainage has been practised spasmodically since 1885 when Cerenville reporting a small series of cases stated that drainage in selected cases held distinct possibilities a a line of treatment

Monaldi more recently has stimulated thought along these lines and since his work on open drainage of cavities many clinics have adopted this course and modified the original technique

The types of operation can be di ided into

1 The introduction of a tube into the cavity
2 The laying open of the cavity as in the drainage of an acute lung abscess

Basically both procedures use the same underlying principle that of decreasing the intracavitary tension by the formation of an artificial stoma Fundamentally however before the cavity can satisfactorily close the draining bronchi must be closed or theoretically they may reopen as a result of the complete healing of the tuberculous bronchitis and re-establishment of the lumen an occurrence which must be rare

III Operations in Which Resection of the Diseased Area Is Performed

Lung resection which is now more and more frequently being undertaken is an admission of failure to close certain types of cavity and is also used for certain lesions not amenable to relaxation therapy

I OPERATIONS EMPLOYING RELAXATION PROCEDURES

OPERATIONS ON THE PHRENIC NERVE

Surgical Anatomy

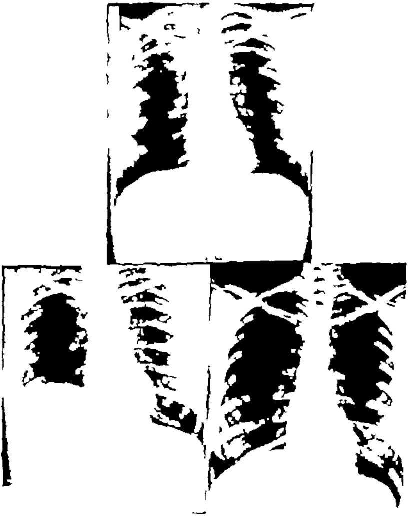
The important anatomical points are

1 *The Origin of the Nerve* The main contribution is from the 4th cervical nerve smaller elements coming from the 3rd and 5th Most commonly the three elements join quickly the nerve being a single entity by the time it reaches the lateral aspect of the scalenus anticus muscle Less commonly the elements from the 4th and 5th may lea e the common trunk of these two nerves going to the brachial plexus either in common with the nerve to subcla ius or separately the element from the 5th nerve only may take the course with the nerve to the subclavius In consequence one element of the nerve may take the normal course of the nerve the remainder generally referred to as an accessory branch taking a course at a lower level joining the portion lower down usually in the chest When the accessory branch goes with the nerve to the subclavius the nerve runs anterior to the subclavian vein and as it joins the main portion of the nerve a loop is formed on which the ein rests

2 *The Position of the Nerv* The nerve in its cervical course lies under the fascia overing the scalenus anticus muscle and crosses the anterior surface of the latter from without inwards Most commonly it can be seen crossing obliquely in the centre of the operati e field It may however cross the muscle relati ely high up in its course and it then courses downwards on the inner margin of the muscle at other times it may course down on the front of the roots of the brachial plexus close

to or under cover of the outer border of scalenus anticus crossing the muscle at a much lower level

It is crossed in the neck by the intermediate tendon of the omohyoid muscle and the transverse cervical vessels and is under cover at any rate in part of the outer portion of the internal jugular vein



b

Fig 45 Mrs W aged 30.

X ray showing cavity in right apex with rounded opacities in midzone

b Condition three months after phrenicectomy Cavity closed but still some infiltration at apex. Note marked rise of right diaphragmatic leaf

Condition two years later Lung fields practically normal. Diaphragm back in normal position.

Thus it will be seen that the phrenic nerve crosses the operative field in the polyhedron formed by the internal jugular internally the brachial plexus as an outer margin, and the upper and lower limits of the field

Interruptions of the phrenic nerve may be permanent or temporary

Permanent interruption is carried out by avulsion of the nerve or resection of long

segments of the main trunk and any accessories This operation is rarely used in the treatment of pulmonary tuberculosis and should be used only when permanent paralysis is con idered to be not only desirable but essential

Temporary interruption is usually carried out by crushing the phrenic nerve and section or crushing of any accessories Other methods such as alcoholisation and freezing have fallen into desuetude

Temporary paralysis of the diaphragm is in common use In fact, the ease with which the operation can be performed has tended to its abuse Commonly it is used

1 For apical cavities of recent origin not more than 2 cm in diameter when an artificial pneumothorax is impossible or undesirable
2 In conjunction with pneumoperitoneum in cases with cavitation in the lower lobe
3 In some cases in conjunction with an artificial pneumothorax when both the apex and the base of the lung are adherent and there are no lateral or mediastinal adhesions

Its use should be restricted and it should not be performed merely in the hope that some benefit may accrue When the satisfactory result has been achieved the patient should be fluoroscoped at frequent intervals and as soon as there is any suspicion of reacti ation of the diaphragm a further operation for recrushing the nerve should be carried out If possible the diaphragm should remain inactive for two years after the cavities have closed

The Operation

The operation is better carried out under *local anaesthesia* by intradermal and subcutaneous infiltration with 0 5 per cent novocain and injection of a small quantity of the solution deep to the fascial investment too great a quantity in this position tends to obscure the operative field

Pre-operative Medication Omnopon 20 mg ($\frac{1}{3}$ grain) and hyoscine (scopolamine) 0.4 mg ($\frac{1}{150}$ grain) are given about three-quarters of an hour before operation

Position on the Table The patient lies flat without a pillow under the head the head being rotated slightly to the opposite side too great a rotation disturbs the relationships of the deeper structures to the skin incision

Incision A transverse incision is made about 1 inch above the clavicle in the line of skin clea age using a natural skin crease if one is present and convenient. The incision should be 1 to 1$\frac{1}{2}$ inches long, its posterior end extending to just in front of the external jugular vein There are two objections to placing the incision at a lower level firstly at lower levels the supracla icular pad of fat will be encountered which may give rise to troublesome but not serious bleeding and secondly the two layers of the fascial sling for the intermediate tendon of the omohyoid have to be tra ersed at this level The higher incision gives simple and direct access to the nerves

The skin and subcutaneous fat are divided until the platysma muscle is exposed small di ided vessels being caught with fine haemostats The platysma is split in the direction of its fibres by separating the blades of probe-pointed scissors (small curved Mayo s) The posterior fibres are then elevated and similarly dissected from the surface of the sternomastoid muscle until the latter s posterior border is identified and freed This gap is now retracted with two small retractors The

method of retraction is the secret of the ease with which the operation is carried out with the retraction there must also be elevation of the tissues so as to render tense the underlying fascial planes and make blunt dissection easy

The direction of the blunt dissection is carried out at right angles to the skin surface When the fascia deep to the sternomastoid has been opened up a retractor with a narrow blade which carries a small light (Nelson s) is inserted under the sternomastoid and this is sufficient to illuminate the whole field The outer margin of the internal jugular vein is then identified and freed in like manner and taken up in the retractor Most often the fascia covering the scalenus anticus is exposed by the manoeuvre or with very little further dissection It is important to keep the fascia intact If it is once torn and certainly if it is taken up by the retractor the phrenic nerve most frequently will go with it, as does the ureter with the peritoneum.

If the phrenic nerve is not immediately obvious the front of the brachial plexus and the outer side of the scalenus muscle are exposed and by following up the outer margin of the muscle the nerve will be found either running parallel to this margin and crossing the muscle lower down, or crossing the outer border of the muscle high up Occasionally the nerve may run deep to an ascending cervical branch of the transverse cervical artery and be thus obscured under these circumstances *examination below the level of the latter vessel will make it obvious*

If permanent interruption of the nerve is desired the fascia covering the nerve is incised and the nerve is freed injected with novocain and then grasped with a pair of haemostats and divided The adherent fascial coverings are detached from the nerve and steady slow traction is made on the forceps the slower the nerve is extracted the less painful will be the process and the longer the segment of the nerve extracted During the extraction it is often possible to feel the rupture of an accessory branch before the nerve itself finally breaks

In the crushing operation the fascia should not be disturbed the nerve is picked *up with dissecting forceps and crushed through the fascia. The ad antage of leaving* the fascia undisturbed is that the tissue planes can be dissected open again with reasonable ease should it be necessary at a future date to recrush the nerve If the fascia has been opened an area of adhesions inevitably occurs over the site where the muscle fibres have been exposed Under these circumstances it will be necessary to carry out the exploration abo e or below the area of adhesion. When the nerve has been crushed the outer border of scalenus anticus is exposed in order to ascertain whether or not an accessory branch is present If one is identified and it is large it should be crushed in the same manner as the main trunk If small it may *be di ided and a small segment removed*

Bleeding is rarely ever serious but may be troublesome It should be controlled by packing one or two small swabs into the wound and leaving them for a minute or two Attempts to secure these small vessels with haemostats only leads to further haemorrhage The wound is closed with two or three clips in the skin, and a small gauze dressing is fixed with adhesive strapping

Accidents of the Operation

Crushing of the Wrong Nerve This has frequently been done; the sympathetic *trunk vagus nerve and even parts of the brachial plexus* ha e been so treated These accidents are quite unjustifiable The course and relationships of the nerve are

quite unmistakable and failure to find it after a careful search is the signal for abandoning the operation for four to seven days when a fresh intervention can be carried out

Severe Haemorrhage can occur either from injury to the external or internal jugular veins or the subclavian vein The external jugular vein often does not appear in the operative field but should it be injured a lateral ligature can be placed on the opening or the vein can be ligated The internal jugular may be opened by too rough usage in separating its outer border especially while operating to recrush the nerve or while operating in cases for which a thoracoplasty has previously been done The opening can be controlled by digital pressure while the wound is enlarged and then a lateral suture can be placed in the vein wall

The subclavian vein has to be torn while evulsing the nerve when an accessory nerve is present which forms a loop around the vein Prevention is better than cure of this complication Any evidence of haemorrhage when the nerve is being evulsed is an indication to stop Serious bleeding requires a difficult procedure to ensure its arrest A few fatal accidents of this nature have been reported

Pneumothorax is a rare complication of phrenic avulsion and is not of serious significance It results from a small pleural tear which can be understood when the close relationship of the nerve to the pleura is considered

SCALENECTOMY

This operation is practised but rarely and then usually in combination with diaphragmatic paralysis and the operation of multiple intercostal neurectomy The rationale of the operation is to prevent the inspiratory elevation of the first rib and allow of its partial descent by detaching the scalene muscles from its upper surface In this way in conjunction with the diaphragmatic paralysis the vertical pull on the apex of the lung is further decreased as is also the volume of the hemithorax When multiple intercostal neurectomy is added, it ensures the degree of immobility of the hemithorax achieved by these procedures

Anatomical Considerations

The operation as originally practised entailed section only of the muscles but it was found that the cut ends became re attached and the function of the muscles was restored in quite a large percentage of cases In consequence, it is advisable to resect about 1 cm of the length of the muscles in order to avoid this The important relationships of the scaleni apart from the phrenic nerve itself are the subclavian artery and vein, the brachial plexus and the long thoracic nerve of Bell The scalenus anticus muscle where it is attached to the scalene tubercle and inner margin of the 1st rib separates the vein from the artery the latter running in a tunnel between the anticus and the medius muscles This tunnel is formed by loose delicate fibrous tissue which surrounds the artery

The brachial plexus emerges from the interval between the scalenus anticus and the scalenus medius, and running down on its posterior aspect is the long thoracic nerve This nerve arises from the roots of the 5th 6th and 7th cervical nerves the upper two roots emerge from the substance of the medius whereas the lower root from the 7th crosses its anterior surface The greatest care must be taken not to damage the long thoracic nerve and also that retraction of the brachial plexus should

be of the gentlest order Injury to the long thoracic nerve leads to winging of the scapula a disability of which the patient bitterly complains Mild trauma of the brachial plexus is the undoubted cause of the pain and paraesthesia from which these patients occasionally suffer

The Operation

The operation is carried out under *local anaesthesia Pre-operative medication* omnopon 20 mg (⅓ grain) and hyoscine 0.4 mg (1/150 grain) is given three-quarters of an hour before operation Intradermal infiltration of the line of incision is carried out with 0 5 per cent novocain and the subcutaneous tissue is generously infiltrated with the same solution Only a small quantity of the solution is injected deep to the cervical fascia because in the first place, large quantities are unnecessary and secondly their use tends to obscure the anatomical details of the operative field

Position on the Table The same position on the table is adopted as for operations on the phrenic nerve except that the head with advantage can be fully rotated to the opposite side (Fig 146 *a*)

Incision The incision is made about 1 inch above the level of the clavicle or slightly lower Its anterior end rests over the posterior part of the sternomastoid and extends backwards to the anterior border of the trapezius

The skin and platysma are divided throughout the length of the incision The external jugular vein is divided between ligatures and the descending cervical branches of the cervical plexus are injected with novocain and retracted or divided as the circumstances indicate

The deep fascia of the neck is then opened and divided in the direction of and for the whole length of the incision failure to do the latter will considerably hamper access to the deeper layers

The supraclavicular pad of fat is now encountered This pad should be divided by blunt dissection sharp dissection only leads to troublesome haemorrhage and may cause inadvertent damage to the main lymphatic channels the thoracic or right lymphatic ducts or even to the spinal accessory nerve

After separation of the pad of fat, the ultimate operative field is exposed It may be found necessary to ligate the transverse cervical vessels if they are inconveniently placed

The phrenic nerve is now identified with its accessories and the fascia covering the scalenus anticus is incised longitudinally The phrenic nerve is injected with novocain but is not crushed at this stage as this would weaken the nerve and make rupture likely when it is retracted. The nerve is retracted inwards and then the anterior surface of the scalenus anticus is cleared of its fascia down to its insertion into the first rib This exposes the third part of the subclavian artery as it emerges from behind the outer margin of the muscle The vein often is not clearly visualised as it tends to drop down behind the clavicle

DIVISION OF THE SCALENUS ANTICUS Division of this muscle is now carried out preferably at a little distance above its costal attachment The greatest care must be taken in dividing the posterior fibres to avoid damage to the subclavian artery (Fig 146 *b*) The loose fibrous tissue in the arterial tunnel is the guide to be looked for It is essential however to divide all the fibres, and timidity in doing so vitiates

the whole operation When the muscle has been completely divided its posterior surface is freed from the front of the brachial plexus and the inner margin of the muscle is visualised before 1 cm of the muscle is excised Blind division of the muscle especially the inner margin may lead to division of the thyrocervical trunk or vertebral artery both of which lie in close proximity

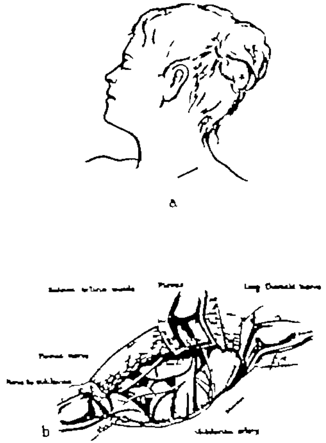


Fig 46.

Position of head for the operation of scalenectomy and incision, which, with advantage could be carried a little farther forwards.

b The operative field after the scaleni have been sectioned. The relationship of the structures are well shown especially that of the long thoracic nerve coming off the posterior aspect of the plexus.

DIVISION OF THE SCALENUS MEDIUS The interval between this and the anticus muscle is defined and the brachial plexus is gently displaced forwards This exposes the long thoracic nerve which is gently freed from the lateral aspect of the muscle The detachment of the muscle from its broad attachment to the posterior part of the upper surface of the first rib is most safely carried out with a rugine as recommended by Alexander This technique minimises the risk of damage to the pleural dome When this attachment is freed, the lower part of the muscle is freed and 1 cm of the length of the muscle is excised The scalenus posticus which is attached

to the 2nd rib is freed by digital pressure from the chest wall down to its attachment, and it can then be cut with scissors directed by the finger and a portion be excised. Needless to say it is essential to see that the nerve of Bell is retracted out of harm's way during the manoeuvres The wound is then closed in layers and covered with a small gauze dressing fixed by adhesive strapping

Accidents of the Operation

The potential accidents have been indicated during the description of the operation No such accident has been experienced personally in a small series of cases but it will be self-evident that the potentialities for considerable trouble are inherent in the procedures unless the greatest care is exercised

MULTIPLE INTERCOSTAL NEURECTOMY

It has already been stated that this procedure is indicated but rarely Alexander who first used this operation in any series of cases considered the operation to be specifically indicated in patients with exudative disease in whom thoracoplasty would be indicated except that they are not fit to withstand the latter intervention. *Manifestly the cases submitted to this operation are unsuitable for artificial pneumothorax* because it is either impossible or contraindicated on account of the character of the disease Furthermore they must have failed to react to the simple procedure of diaphragmatic paralysis which with scalenectomy should be in any case combined with this operation

The careful staging of the operation of thoracoplasty and the judicious use of extrapleural artificial pneumothorax *have decreased the already limited indications* for this operation first set down by Alexander

Anatomical Considerations

The intercostal nerves will be found lying in the subcostal groove in a common sheath with the artery and vein, the vein being above, next to the rib and then the artery and then the nerve in the lowest and most accessible *position. The* neuro-vascular bundle lies here between the external and internal intercostal muscles behind the angle of the rib the bundle lies on the posterior intercostal membrane the internal intercostal muscle being absent in this position The interval between the two intercostal muscles can usually be recognised by a thin layer of loose areolar tissue but if this is not recognised and a sufficiently long length of external intercostal muscle has been incised, the direction downwards and backwards of the fibres of the internal intercostal muscle should be easily recognised. If by any chance the pleura is reached and incised this is of no great moment as in these cases the lung is adherent to the chest wall

The Operation

The operation is performed in two stages In the first stage portions of the 2nd to the 5th nerves inclusive are excised In the second stage the 6th to the 11th nerves are exposed and crushed

Omnopon 10 mg (⅙ grain) and hyoscine 0 4 mg (1/150 grain) are given *pre-operatively* The operation is done under *local anaesthesia* The line of incision is infiltrated with a solution of novocain 0 25 per cent and amethocaine 1 2000 with

6 minims of adrenaline to each 100 c c of the solution The intercostal nerves are injected after the muscle planes have been divided

Position of the Patient The patient is placed in the lateral position and held in the position by supports from the front of the chest and the front and back of the pelvis with a soft pad under the axillary part of the chest the latter to increase the width of the intercostal spaces

Incision As the patient will most probably be submitted to a thoracoplasty at a later date the incision should be planned with this in view The incision for the first stage is the same as the vertical portion of the thoracoplasty incision placed between the vertebral border of the scapula and the spinous processes but nearer to the latter Its upper end lies a little above the level of the spine of the scapula and it extends downwards to the level of the 7th rib

The skin is divided and after haemostasis has been secured skin towels are fixed in position The muscles are then incised and the ribs with the serratus posticus superior come into view The latter muscle is dissected from its costal attachments and excised and the scalenus posticus is similarly treated Local anaesthetic is now injected into the intercostal spaces the injection being made backwards from the outer edge of the erector spinae Too large a quantity of the solution should not be injected, as it will infiltrate forwards and tend to distort the field of operation

The external intercostal muscle is now incised for about 1¼ inches from the outer margin of iliocostalis and the incision is deepened until either the inter muscular fascial plane or the fibres of the internal intercostal muscle are identified The upper fibres of the external intercostal muscle are now grasped with suitable forceps such as Styles tissue forceps and elevated and with a little blunt dissection the sheath of the neuro-vascular bundle comes into view This is incised and the intercostal nerve which may be in two branches is identified and injected with anaesthetic solution. The nerve both parts if there are two branches is divided at the posterior end of the wound and then pulled forwards until an inch or so can be excised A fine running suture bringing the fascia over the line of incision is advisable in view of possible future interventions as this prevents fixation of the tissues at these points Each of the four nerves is similarly treated but it will be found that the 2nd nerve is not infrequently well under co er of the ribs

The wound is now closed in layers and a soft dressing is fixed with adhesive tape

The *second stage* of the operation is carried out through downward extension of the same incision, a similar technique for exposure of the nerves being used but instead of excising a portion of the nerve it is crushed with a pair of haemostatic forceps

EXTRAPLEURAL ARTIFICIAL PNEUMOTHORAX

Operations in ol ing stripping of the parietal pleura with the underlying lung away from the chest wall and mediastinum (extrapleural pneumolysis) have been carried out for many years the remaining space being filled by a variety of substances including muscle fat wax and latterly balls of plastic material The use of air to fill the space was not put on a firm base until 1937 when Graf and Schmidt reported a series of cases satisfactorily so treated The use of foreign substances to fill the space had fallen into disuse until recently The introduction of modern plastics has led to their use generally as balls These substances produce little or no tissue

reaction and in consequence eliminate the chief objections to the use of wax, i e extrusion of the wax either through the chest wall or the bronchial tree, the latter almost invariably being associated with infection

Early experience with air refills led to disappointment in the main because of the limited area of pleura which was mobilised and in consequence the lung tended to re-expand and fill the space The more extensive mobilisation practised in the modern operation has overcome this objection, and the artificial pneumothorax thus established can with reasonable care be easily maintained. In the earlier reports *the occurrence of subcutaneous emphysema was stressed and no doubt acted as a* deterrent to development of the procedure At present it is clearly appreciated that the air is confined in the thorax by the endothoracic fascia, and if the wound in the chest wall which results from the resection of a rib is closed with an air tight suture often no emphysema of the tissues occurs and even when it does it is only slight Serious subcutaneous and intramuscular emphysema occurs only when there is a continuous valvular bronchial leak which produces an ingravescent pneumothorax

This operation is a quite obvious substitute for an intrapleural pneumothorax when the latter cannot be established but it does not constitute an alternative to the operation of thoracoplasty as the indications for both procedures differ

The ideal indications for this operation are seen in the early case with cavities centrally placed not more than 4 cm. in diameter and without gross surrounding infiltration Some workers have treated giant cavities by this method but this is to be deprecated unless the operator has great experience with this procedure.

The Operation

Pre-operative medication consists of omnopon 20 mg ($\frac{1}{3}$ grain) and hyoscine 0.4 mg (1/160 grain) The operation is carried out under *local anaesthesia* using a solution of novocain 0 25 per cent and amethocaine 1 2000 with 6 minims of adrenaline to each 100 c.c All layers of the chest wall are infiltrated in the line of the incision A paravertebral block of the 2nd to the 8th intercostal nerves is carried out It is true that in many cases this extensive block may not be necessary as in one or two cases, the nerve block having been inadvertently omitted the operation was done without apparent discomfort Nevertheless this cannot be anticipated in every case and the nerve block should be carried out

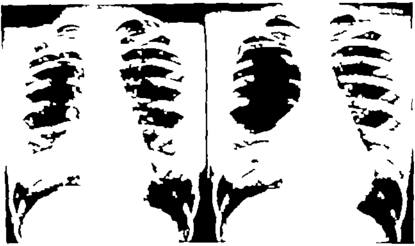
Incision The incision should be part of the thoracoplasty incision, because if extrapleural stripping is found to be impossible or inadvisable it will be necessary to proceed to a thoracoplasty The incision extends from the level of the 3rd rib above to the level of the 7th rib below nearer the spinous processes than the vertebral border of the scapula The skin is incised and after haemostasis has been secured skin towels are fixed to the wound edges The muscular layers are preferably divided as splitting the muscles in the direction of their fibres only leads to limitation of the area of exposure

RIB RESECTION When the ribs are exposed, a length of the 5th or the 6th rib is resected, not less than 3½ inches and preferably 4 inches long The periosteum should be elevated from the rib with the greatest care so as to enable an air tight suture of the wound to be made later Section of the rib should be made posteriorly under cover of the erector spinae but not as far back as the transverse process This

leaves a small posterior stump of the rib which will facilitate resection of the regenerated portion should it be necessary at a later date to do a thoracoplasty

The choice of the 5th or 6th rib is preferable to the 3rd or 4th It is much easier to work upwards over the apex from the lower position than it is to continue the pleural stripping downwards from the upper one

STRIPPING OF THE PLEURA When the rib has been resected the periosteum is divided Deep to the periosteum posteriorly fibres of the internal intercostal muscle will be found crossing the space These latter fibres are divided and the extrapleural plane is entered In fat subjects it is not uncommon to find a fair amount of extrapleural fat in this position this is better left attached to the pleura and stripped down with it because the fat is intimately attached to the pleura and an



a *b*

Fig 47 Miss D B., aged 26 *Jan 1944* Diagnosed as pulmonary tuberculosis. *Apr 1 1944* Artificial pneumothorax attempted. *Sept 1944* Admitted to hospital No sputum. BSR X-ray showed two cavities in upper lobe of right lung. Rest of lung fields normal

a, X-ray showing infiltration and cavitation right apex. *Oct 5 1944* Right extrapleural pneumothorax Uneventful convalescence *March 194* Discharged. Sputum negative BSR 4. *Jan 1949* Quite fit and well Asymptomatic

b X-ray shows extrapleural artificial pneumothorax No evidence of cavitation.

attempt at its separation may lead to perforation of the pleura The pleura is separated from the endothoracic fascia as far as possible under vision and by blunt dissection a slightly curved closed pair of scissors serves this purpose well When the stripping is going easily it can be continued with small gauze swabs held in long, curved artery forceps If there is a tendency to go outside the endothoracic layer this should be corrected by using the closed scissors The pleura should be stripped away from the lower lip of the wound at an early stage because if it is left until later the margin of the wound is pulled down by the retracting pleura and rolls over on itself making separation difficult.

The stripping of the pleura is in this way carried out over the dome of the hemithorax and then downwards over the mediastinum, over the aortic arch on the left side and the vena azygos on the right side that is, to the lung root Posteriorly

laterally and anteriorly the stripping is carried out to the level of the 8th rib posteriorly

When the stripping is being carried out on the mediastinum the patient not infrequently develops a cough each time the mediastinum is touched. This reflex cough can be abolished by injecting a 1 per cent solution of novocain around the vagus nerve It is necessary to give five to ten minutes rest to allow the anaesthetic to act before proceeding with the stripping

In this way a wide mobilisation of the underlying lung is obtained and no difficulty will be found in maintaining the artificial pneumothorax During the stripping a tendency for the pleura to fold on itself will be noted, especially in those cases in which the pleura is not universally adherent to the underlying lung This edge must be mobilised to the required level because the ultimate size of the extrapleural space depends wholly on the level to which the pleura has been detached from the chest wall

CONTROL OF BLEEDING During the stripping there may be some bleeding which, although never serious should be controlled with a diathermy point. Serious haemorrhage can occur only if the correct plane of cleavage has been departed from or if *stripping has been persisted in when the case is unsuitable* The case becomes unsuitable when there has been a serious degree of pleuritis so that the pleura is firmly stuck to the chest wall Under these circumstances the probability that the underlying lung is grossly involved is considerable, and because its own blood supply via the bronchial arteries is diminished an adventitious blood supply comes from the vessels of the chest wall Mobilisation of the pleura in this instance leads to cutting off of the adventitious blood supply which leads to a further extension of the underlying disease possibly as a result of a quiet necrosis and the disease eventually extends to the extrapleural space It is therefore unwise to proceed with the pleural strip when it becomes difficult, and it is much wiser to abandon the operation and proceed to a thoracoplasty preferably at a later date

SUTURE OF THE WOUND When the stripping of the pleura has been satisfactorily carried out the wound in the chest wall is closed. The sutures are commenced both at the anterior and posterior ends of the incision and meet in the centre The first part of the suture embraces the rib end and is tied. The suture then passes above and below the periosteum, giving strong purchase and standing all the tension that is necessary to close the gap The muscles are next closed in two layers and afterwards the skin, the wound being covered by a soft dressing fixed by adhesive plaster

Post-operative Care

The patient should be kept reasonably quiet during the first four or five days. Straining of all kinds should be avoided if possible, as at stool, severe bouts of coughing or vomiting

The pressures in the space should be maintained at a mean atmospheric reading for the first ten to fourteen days Opinions vary as to the necessity for aspirating the fluid which invariably collects in the space some operators insist on keeping the space as dry as possible in the post-operative period, while others do not aspirate the fluid at all unless there is evidence that haemorrhage has occurred Whichever method is adopted the space becomes dry at the end of about a month No good purpose seems to be served by repeated aspirations and when the added risk of

infection attendant on repeated aspirations is considered the more conservative policy i preferable

The intervals of air refills vary in individual cases At first the pressures are adjusted daily or every other day After the first week refills are carried out about every three days and later the interval can be extended It is the general practise to fill the extrapleural space until positive pressure using pressures of between 10 and 20 cm of water The only indication for the use of positive-pressure filling is radiological evidence that the space is being obliterated a mean zero reading is all that is necessary

Complications of the Operation

The complications have already been envisaged i e haemorrhage and infection of the space

Haemorrhage This is a not uncommon complication; in fact a certain amount of oozing into the space occurs in every case but this is of no significance Serious haemorrhage however may occur usually twenty four to forty-eight hours after operation It is almost invariably of venous type and most probably results from the dislodgement of a clot from an open-mouthed vein Two to three pints of blood may be lost into the space in a short space of time Although some fatal cases have been reported prompt recognition and treatment should avoid such a catastrophe Blood transfusion and aspiration of the accumulated fluid should be carried out the latter fairly promptly if the quantity effused is large so as to combat the accompanying physiological disturbance In many cases, the first symptom complained of is dyspnoea In others an increasing area of surgical emphysema of the chest wall is noticed, due to displacement of the air from the space by the effused blood

Clotting occurs not infrequently and is recognised by failure to aspirate any reasonable quantity of blood, or by the irregularities in the effusion which are shown radiologically When this has occurred, the patient should be returned to the theatre the wound reopened and the clot turned out. Failure to do this will at the best lead to obliteration of the space and at the worst to infection

Infection Infection in these cases may result from damage to the lung by the exploring needle when an attempt is made to aspirate all the fluid from the space The lower boundary of the space is formed by the parietal pleura covering the lung and because of the weight of the contained fluid is convex below Just below the level of the attachment of the pleura to the chest wall is a thin fringe of lung and if the exploring needle is inserted too low lung tissue may be traversed and infection from the lung may be carried into the space

Infection may be pyogenic or tuberculous Pyogenic infection is due to a failure of surgical technique either during the operation or in subsequent needling of the chest This should not occur and is in fact very rare When it has occurred it can be controlled chemotherapeutically Since the advent of the antibiotics there should be no need to drain the space

Tuberculous infection is more common and its cause has already been discussed It is true that tuberculous infection of the extrapleural space is not as serious as that of the intrapleural space The patients are not as toxic and the condition is more easily controlled Aspiration of the fluid leaving the pressures highly negative will in a large percentage of cases convert a purulent effusion into a sero-sanguineous one

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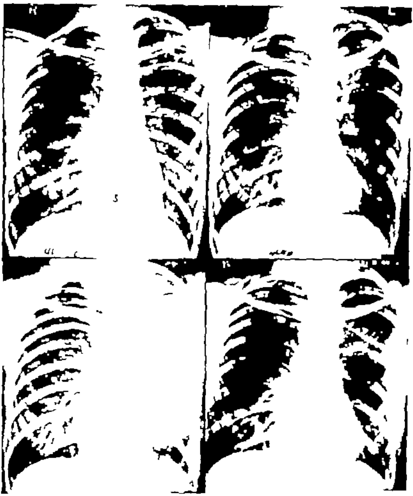
in the course of two to three weeks Aspirations are carried out twice or thrice weekly When the latter stage has been reached pressures are returned to a mean

a *b*



c *d*

Fig 48 Miss O C aged 25

a X-ray shows cavitation of left upper lobe

b After induction of left artificial pneumothorax which was followed by pyrexia and haemoptysis. Artificial pneumothorax discontinued July 26 1946 Left artificial extrapleural pneumothorax established through bed of 6th rib Post-operative course satisfactory until Jan 10 1947 when patient was re-admitted to hospital with staphylococcal infection of the extrapleural space

c Massive effusion into extrapleural space nearly filling hemithorax is evident Aspirations and introduction of penicillin satisfactorily controlled infection.

d Same patient twenty months later

atmospheric pressure and in favourable cases the effusion disappears When the case does not react to this simple line of treatment, streptomycin both parenterally and locally will control the infection

OPEN DIVISION OF ADHESIONS

This is an operation which has been practised off and on since the introduction of the radiographic control of artificial pneumothorax In fact the earliest essays at division of adhesions was practised in this manner On the introduction of the closed method by Jacobeus the open method wa abandoned Later in the early 1930 s the operation was revived and is still carried out in some centres routinely in an attempt to handle the cases in which thoracoscopic division is impossible Reports vary considerably as to the value of the procedure Personal experience with the operation was that the immediate results were gratifying, but in a follow-up of the cases over a period of three to fi e years the incidence of tuberculous empyema was just over 30 per cent a rate which was considered to be prohibitively high and the operation was abandoned It is possible that the cases treated personally were unsuitable for any type of division of adhesions More recently many Scandinavian centres have again taken up the operation but no long-term follow-up of the cases has been performed

The operation performed is identical with that for the production of an extra pleural artificial pneumothorax up to the point where the rib has been resected The pleura is then opened and the wound spread with a rib spread The adhesions are then detached from the chest wall by incising the pleura near the base of the adhesion, stripping it off extrapleurally and dividing the pleura which still holds it to the chest wall or mediastinum. Haemostasis is carried out and the wound is closed as previously described

THORACOSCOPY AND CAUTERISATION OF ADHESIONS

It is generally agreed that all adhesions in an artificial pneumothorax should be cauterised, if this can be safely undertaken but with the following exceptions

Firstly when there is a suspicion of the presence of a tuberculous bronchitis affecting bronchi other than those draining the cavity This really constitutes a contra-indication to the artificial pneumothorax itself but especially so to the di ision of adhesions because the lobe or lung promptly becomes atelectatic and in a large percentage of cases not only fails to re-expand but is commonly followed by a superimposed pleural infection

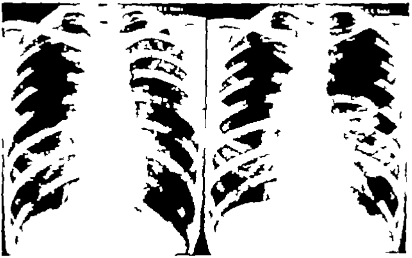
Secondly when there are large apical distension cavities especially when these are associated with surrounding infiltration These cavities are liable to rupture as a result of overdistension possibly due to the cutting off of a peripheral blood supply This complication is undoubtedly the most serious of all complications

Although sometimes a decision can be made from a study of the radiographs that in a given case the adhesions are not cauterisable, generally speaking it is impossible to decide whether the adhesions are cauterisable or not before thoracoscopy a point which should be explained to the patient

This decision depends on certain factors In particular the length and distribution of the adhesions and the state of the pleura The length of the adhesions depends to a large extent on the degree of invol ement of the endothoracic fascia in the inflammatory reaction The parietal and visceral pleurae become attached as a direct result of the underlying lung lesion. In early cases when an artificial pneumothorax is induced the adhesions are formed by the drawing out of the parietal pleura from the chest wall When the disease is older or the inflammatory reaction is more

severe it extends through the parietal pleura to the endothoracic plane with the result that the parietal pleura itself becomes firmly attached to the chest wall The adhesions in this case contain lung tissue which is itself virtually attached to the chest wall The length of the adhesions in the first group will vary but generally speaking for safe division they should be at least 1 cm. long If they are shorter than this there is a risk that the pulmonary end may be charred and the lung tissue damaged especially if the adhesion is attached to the artery or vein and must needs be divided near the centre This latter position presents the greatest difficulty and danger and cauterisation in this area should be undertaken only when a certain degree of proficiency has been acquired

As a general principle it is wiser not to commence dividing the adhesions until it has been determined that all the adhesions present can be satisfactorily divided. The division of a few usually lateral ones, not only leads to disappointment in the



a *b*

Fig 49. Miss P M. C. aged 27

a, X-ray showing cavitation and infiltration of left apex.
b After thoracoscopy and division of adhesions with cavities closed and lung quite free

majority of cases with regard to cavity closure but also their division may so alter the strains and stresses on the remaining adhesions as to lead to an extension of the disease to the pleura and to an empyema. There can be no doubt that infection of the pleura overloads the patient about 100 per cent, apart altogether from the more extensive and prolonged surgical treatment which he has to undergo It is far wiser to abandon at once an unsatisfactory artificial pneumothorax, which cannot be made perfect, than to run the risk of an empyema by its maintenance.

The Operation

The operation is done under *local anaesthesia* by infiltration of the skin and intercostal space at the site of puncture

Pre-operative medication with omnopon 20 mg ($\frac{1}{3}$ grain) and hyoscine 0.4 mg ($\frac{1}{150}$ grain) is advisable although it is a distinct disadvantage at operation if the

patient is drowsy or asleep Before the operation is begun the patient should be told that he may feel occasional pain which will be due to the heat of the cautery and that if this is so he must make it known so that a rest can be given but that it is important that he should not move as serious damage may result Similarly due warning should be given of any desire to cough so that the instruments can be removed

Armamentarium The armamentarium necessary for the operation includes first a refill pneumothorax needle fitted with a blunt-ended stilette which moves easily in the needle and can be projected an inch or so beyond the needle A set of thoracoscopes and cauteries are required. The type of thoracoscope and cautery will depend on whether the single-cannula or the double-cannula technique is employed I favour the double-cannula technique and this consequently will be described The double-cannula method has the advantage that both cannulae can be used, if desired for the thoracoscope or cautery and a much better general view of the chest is obtained Also because the cutting point is usually at right angles to the line of vision, one gets as near to binocular vision as is possible through a monocular telescope Two telescopes are advisable one right-angled with a visual field at right angles and the other fore-oblique, at 120 to 130 degrees to the long axis of the instrument. Through the former a long-distance view may be obtained but the latter is more useful when a close-up view is desired

It is also useful to have one articulated cautery in which the point can be made to travel to any position up to 90 degrees to the axis of the shaft of the instrument this allows adhesions in all positions to be sectioned with the cautery point at right angles to their long axis Cutting a firm adhesion which does not fall away from the chest wall with a straight cautery leads to charring and in some positions the section of the adhesion with a straight cautery would of necessity be done so obliquely as to be dangerous

The technique in the double-cannula method is more difficult for the beginner and it needs more practise to co-ordinate the movements of both hands to keep the site of operation in vision and the cautery point moving in the correct manner The single-cannula method has the distinct advantage for the beginner that the cautery point and the telescope move as a whole but the vision is completely monocular and the approach to the adhesions is limited Persistence in mastering the double-cannula technique will be amply repaid in the greater scope afforded by this method

Position of the Patient. The patient lies in the lateral position with a soft pad under the axilla but without a chest rest which tends to interfere with the ease of manipulation of the instruments The arms are placed, one under and the upper one over the pillow so as to expose fully the lateral aspect of the chest When the skin has been prepared and the towels are in position a large skin wheal is made over the site of the first puncture and the intercostal space and subcutaneous tissues are infiltrated with 10 to 15 c c of the anaesthetic solution

Puncture Site The site of the first puncture varies with the operator The third or fourth interspace just in front of the midaxillary line gives a good approach this being the area of the chest wall where adhesions least commonly occur

Insertion of Stilette The refill needle and its stilette are inserted through the chest wall into the pleural cavity and the stilette is then gently pushed on through the

needle If no resistance is felt with the stilette it can be assumed that a satisfactorily deep pleural space is present at this point and the operation can be proceeded with. Resistance, however indicates either that an adhesion is present near the site or that the lung is at the level at which the resistance is felt, this level being easily assessed by the length of stilette beyond the needle on its withdrawal. Under these circumstances it may be necessary to choose a fresh site

Insertion of Trocar and Cannula Thoracoscope A small incision is now made through the skin and the trocar and cannula are inserted through the centre of the inter costal space One of the flat surfaces of the pyramidal head of the trocar should be parallel to the lower margin of the upper rib in order to minimise the risk of wounding an intercostal vessel After the trocar has been withdrawn, the right angled thoracoscope is introduced and the adhesions are inspected special attention being paid to the mediastinal aspect over the vessels to the apical region and to the costovertebral gutter The mediastinal and apical regions are often more easily seen with the fore-oblique telescope In the former position the lung can be pushed away from the mediastinum with the telescope and the adhesions made taut if they are slack. If from this point of view no adhesions are visible which are not cauterisable the site of the second puncture is anaesthetised This site can be chosen under thoracoscopic control so that it is not placed in such proximity to an adhesion as to make it inaccessible either visually or to the cautery Commonly this will be in the 6th or 7th interspace behind the vertebral border of the scapula, the shoulder being pushed well forwards There may be a tendency for the beginner to place the cannulae as high in the chest as practicable but this is a technical error which will quickly be recognised if it is practised. There should of course be no hesitation in putting in a third cannula should this be necessary When the second cannula is in position the adhesions are again inspected before a final decision is taken that all the adhesions are cauterisable

Cauterisation The cauterisation is usually more easily performed if the cautery is introduced through the anterior cannula. The intercostal spaces here are wide and the chest wall is flatter and in consequence a greater range of movement is possible For short adhesions onto the subclavian artery and vein however it will be found easier if the cautery is used through the posterior cannula because the adhesions which may not be tense can be rendered so by the manoeuvre described above The cautery is used at red heat too hot a cautery cuts too quickly and the vessels are not sealed, while too slow a cautery leads to charring If a vessel even though small, does bleed it should be promptly sealed with the cautery Failure to do this leads to seepage of blood over the operative site and to charring with smoke formation, thus obscuring the field of vision If at all possible the adhesions to the mediastinum and in the costo vertebral sulcus are divided first, leaving those in the axillary region until last Early section of the axillary adhesions allows the lung to fall down on the mediastinum and increases the difficulty of their section.

The adhesions to the chest wall are sectioned as close to the chest wall as possible and if they are at all thick, they are enucleated from the chest wall In the latter manoeuvre the parietal pleura is divided at or a little distance away from the base of the adhesion and if necessary the endothoracic fascia is divided until the inter costal muscle or periosteum is laid bare Dissection is carried out in this layer by a combination of cold stripping and cauterisation until the base of the adhesion is detached and then the pleura on the opposite side is cut with the cautery Some

operators enucleate large areas of attached lung in thi way but in average hands the risk of empyema in thus detaching adherent lung i so great as to preclude its use The cutting of the adhesion hould be done with light stroking movements and not by resting the cautery on the adhesion as the latter wastes time and leads to unnec essary charring All the adhesions should if possible be cut at the one sitting and this can usually be accomplished in twenty or thirty minutes However it may on rare occasions be necessary to complete the operation at a second sitting once the division of a given adhesion has been commenced it should be completely divided at that stage

After all the adhesions have been divided the sites of the sections are inspected to see if there is any haemorrhage and any point still bleeding is sealed with the cautery The sites of the cannulae are also examined and if there is any sign of haemorrhage at either cannula it can usually be controlled in the following way An articulating cautery is introduced into the cannula so that its tip is just visible and the point is flexed until it touches the cannula wall on the side facing the intercostal The cannula is then withdrawn until the opening is level with the open ing in the pleura and it is pressed upwards towards the subcostal groove The control knob of the cautery is turned up higher the patient is warned that it may hurt and the cautery is switched on and kept in position until charring commences

Closure of Wound The cannulae are now withdrawn and the skin wound is closed with a suture Firm pads are strapped over the punctures

Release of A from Pleural Ca ity It is often an advantage to take some air off the pleural cavity because the mediastinum tends to move to the opposite side after the adhesions have been cut This can be done with an artificial pneumothorax machine but what serves equally well as a temporary measure is to get the patient to take in a few deep breaths with the cannula occluded during inspiration and open during expiration Pressure on the chest to exaggerate the expiratory phase is also of help

The patient is warned to avoid coughing violently or to make any effort with the glottis closed for forty-eight hours following the operation to minimise the risk of squeezing air out into the tissues of the chest wall

Post-operative Care

Collection of fluid occurs in a high percentage of cases and unless this is minimal it should be aspirated otherwise an obliterative pleuritis may occur Refills should be gi en when indicated by radioscopic or radiographic control At first these will be required every two or three days, and at longer intervals later

Accidents of the Operation

Large vessels such as the subclavian artery or innominate vein, may be acci dentally opened More commonly however an intercostal artery or the internal mammary or one of its branches is damaged

The larger essels are injured when an ill-advised attempt is made to di ide short adhesions to these structures

The smaller ones are opened either by the trocar point or during the enucleation of an adhesion from the chest wall Under the latter circumstances the vessel is often dislocated by the retracting adhesion and may be opened quite easily

Rarely it may be necessary to open the chest to control the bleeding

THORACOPLASTY

The operation of thoracoplasty is the most severe of the relaxation procedures. The reason is to be found not only in the greater extent of the actual surgical intervention but also in the fact that the stability of the chest wall will be interfered with consequent upon the resections of the ribs, this latter point being of considerable importance. The removal of the ribs with mobilisation of the apex of the lung allows the area of lung so affected to move paradoxically in that during inspiration the freed area of lung collapses and during expiration it inflates. The range of paradoxical movements is much greater if the apex is soft and conversely less when the apex is solid. Thus in early cases where there is little fibrosis and atelectasis, paradoxical movement is most severe. The effects of paradoxical movement are twofold: physiological and pathological.

Physiological Considerations

1. The air entering and leaving the affected area is in the main taken from and returned to the uncollapsed areas of the lungs, a pendulum swing of air as occurs in the collapsed lung in an open pneumothorax, which is tantamount to increasing the dead space. In addition, the air entering the affected area has a low oxygen and high carbon dioxide content, both increasing the patient's dyspnoea.

2. The mediastinum, when soft, moves correspondingly and this mediastinal flutter sets up reflexes with corresponding cardio-respiratory embarrassment.

Pathological Considerations

1. Lymph returns from the lymphatic spaces of the lung to the blood stream as a result of pulmonary movements. When the lung is subject to paradox, the rate of lymph flow is increased. Thus, in these cases, the dose of toxin-laden lymph is considerably increased per unit of time and a severe degree of autotuberculisation may ensue.

2. Infected secretions from the affected area can be aspirated more easily into the uncollapsed area by this mechanism. Such aspirated secretions can be efficiently handled by the sound side, but on the operated side the cough mechanism is seriously hampered as a result of the interference with the normal architecture of the chest and either collapse of the lower lobe or a patchy spread of the disease ensues. This liability is further increased if the hemidiaphragm of the same side has been paralysed.

The above considerations underlie the necessity for the staging of the operation, each case being assessed individually, and the length and number of the ribs and the extent of the mobilisation at each stage being decided according to the length of history, the degree of toxicity, and last but not least, the mobility of the apex.

The *length of rib resected* is as important as the number. This is especially so in the upper ribs. The 1st rib can be removed in its entirety in all cases, but when the apex is soft, 2 or more inches of anterior end of the 2nd rib should be left and the 3rd rib should not be taken farther forward than the posterior axillary line, in order that the relatively unsupported anterior part of the chest will not be uncovered. At a future stage these ribs can be resected further forwards, as by then the apex has acquired a covering which renders it less mobile.

The *number of ribs* taken at each stage also varies; in the average case, portions of

the first three ribs may be taken but there should be no hesitation in restric the number to two one and a half or even one rib When the apex is firm hard there is no objection to removing the small portions of the posterior en the 4th and 5th ribs with a corresponding increase in the extent of the a mobilisation

The *interval between the stages* is generally fourteen days This is the optir time from the point of view of ease of technique and the patient s cond generally allow of operation quite safely after this interval After a further v the tissues tend to get stiff and friable and remobilisation of the apex is corresp ingly more difficult a difficulty which increases with further waiting In fact easier to remobilise an apex six months after a first stage than six weeks How it cannot be too strongly stressed that further stages should never be undert unless the patient s condition will allow and no consideration of the incre operative difficulty resulting from the longer wait should be allowed to sway surgeon into a premature intervention

Indications for the Operation

The indications are extremely difficult to tabulate as so many considerations influence the choice of case Certain general principles however can be laid d

Firstly It is assumed that other simpler methods of treatment have been and failed, that there are definite contra-indications to their usage, or indica that their use would lead to a disappointing result In the latter group the anator characteristics of the lesion, i e the size of the cavities and the evidence of fix ot the lung to the chest wall as shown by contraction of the chest wall on affected side are indications that nothing short of a thoracoplasty will contro lesion

Secondly In cases with bilateral disease it is as a general rule essential tha contralateral lung should either be controlled or stabilised before operatio undertaken on the worse side

Thirdly In the majority of cases the course of the disease is fluctuating In the relati ely stable course of the chronic case is interrupted by periods of toxae when both the general and focal symptoms are increased and there may or ma be some radiographic evidence of slight progress of the disease In view of this necessary to conduct the operation when the patient s resistance is near its p

This decision is arrived at by a careful study of the patient s history serial x and serial blood-sedimentation rates The importance of the latter lies chiefly i variations a rise from 20 to 60 mm being of more significance than a steady of 75 mm. over a period of months A falling sedimentation rate can be taken indication of improvement and for a further period of waiting until the stable shows that the optimum time has been reached

Classification of Cases

Cases can be classified under the following headings

1 *Stable Chronic* the case which is apyrexial and non toxic and in whicl sedimentation rate is consistently low e g 18 to 10 mm and in which t are no general symptoms

2 *Relapsing Chronic* the case whose course is like that of the former but with toxic interludes of varying duration, the general condition returning almost but rarely quite to the same level as before the interlude
3 *Slipping Chronic* the case in which the course is steadily downhill There is a moderate fever and loss of weight, and a slow but steady radiological deterioration This type of case presents a serious problem and is the only group in which, if operation is to be undertaken at all delay is detrimental as successive weeks or months show only further deterioration These patients often benefit considerably from a short course of streptomycin which may arrest the downward course sufficiently to warrant operation
4 *Hopeless* the case which is more advanced than that in the former category and differs in its severity and in that deterioration can be measured in days and weeks instead of weeks and months

When a decision to operate has been arrived at, the whole plan of treatment should be fully discussed with the patient as only in this way can his full co-operation be obtained The majority of these patients have spent a considerable time in tuberculous communities and are fully cognisant of the various forms of treatment, and discussion with them is an important part of their treatment as in this way they acquire that peace of mind which is almost as essential to a satisfactory result as the operation itself

Types of Thoracoplasty

There are two types of thoracoplasty—lateral thoracoplasty and thoracoplasty with apical mobilisation

Lateral Thoracoplasty is reserved in the main for tuberculous empyema and entails solely the resection of the ribs over the area to be relaxed

Thoracoplasty with Apical Mobilisation is now used practically universally in this country for cases with apical cavitation The mobilisation of the apex can be carried out either wholly extrafascially or extrapleurally on the mediastinal aspect of the lung The latter type of mobilisation technically is the easier to perform, but the extrafascial type of operation has the following advantages (1) The risks of damaging the pleura and in consequence the lung are much less when separation is made in the extrafascial plane (2) The apex of the lung remains at the level to which it has been mobilised because the fascia retracts with the pleura and being an inelastic membrane maintains the position of the apex When mobilisation has been carried out extrapleurally the apex creeps up between the first and second stages for the distance of a rib and an intercostal space (3) In cases in which there is considerable peripleuritis it is only possible to carry out the mobilisation extrafascially This latter consideration is important, and in consequence, it is wiser to carry out the *extrafascial operation in all cases In this way* the operator becomes so conversant with the anatomy of the mediastinum that in difficult cases especially those subjected to re-operation, the anxiety of the operator and the risks to the patient are considerably minimised

Anatomical Considerations

For the proper conduct of the operation, an anatomical appreciation of the endothoracic fascia is necessary

The whole of the outer surface of the parietal pleura is covered by a layer of fascia which is called the endothoracic fascia Over the costal surface of the pleura the latter is attached to the chest wall by a layer of loose areolar tissue, which some times contains a con iderable amount of fat especially so in the region from the angles of the ribs backwards This loose layer also extends over the diaphragmatic surface as far as the central tendon where the pleura becomes firmly and intimately adherent

At the inner margin of the first rib the fascia becomes a fairly dense continuous sheet (Sibson s fascia or the fascia of the dome of the pleura) *The function of this*

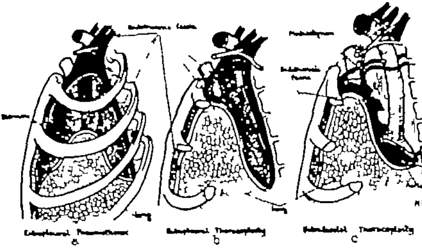


Fig 5 Diagrammatic representation of the essential differences in the planes in which mobilisation of the apex is carried out

Extrapleural artificial pneumothorax. The separation is entirely in the extrapleural plane, and inside the endothoracic fascia where this fascia forms a sheet as on the mediastinum and over the dome of the pleura.

b Thoracoplasty with apical mobilisation in the extrapleural plane on the mediastinal surface Here the fascia is ruptured at the lev l of the internal mammary artery and the mediastinal investment of fascia remains in position

c, Thoracoplasty with true extrafascial mobilisation. In this case the whole endothoracic fascia is stripped down with the lung on all aspects, after section of the bands attaching it to the neck of the first rib transverse process of the seventh cervical vertebra, and the fascial planes of the neck.

layer is to confine the lung within its normal limits and is best appreciated when the fascia has been ruptured and a hernia of the lung into the root of the neck has resulted

Sibson s fascia is attached to the inner margin and neck of the 1st rib and to the tip of the transverse process of the 7th cervical vertebra laterally The fascia then ascends to invest the dome of the pleura, and on its inner surface is continued down as a thinner sheet on the mediastinal aspect of the pleura ultimately to blend with the lateral aspect of the pericardium

The 1st dorsal nerve which arises within the thorax has to perforate the fascia in order to reach the upper surface of the 1st rib on its way to the brachial plexus In doing so it separates the attachments of the fascia to the neck of the 1st rib from that to the tip of the transverse process of the 7th cervical vertebra Thus are

formed the first two bands of Sebileau The third band of Sebileau is formed by the investment by the fascia of the posterior aspect of the scalenus anticus muscle with some of the fibres of this muscle which are inserted into Sibson s fascia itself The subclavian artery arches over the dome of the fascia to reach the upper surface of the 1st rib and in doing so is in close relationship with the anterior margin of the second band and the posterior margin of the third band

The second band is triangular in section, lying between the subclavian artery in front and the vertebral body posteriorly In about 40 per cent of cases it contains muscle fibres from the scalenus medius muscle and in about 1 per cent of cases there may be direct continuity between the fibres of scalenus medius and anticus, forming a sling, often tendinous around the subclavian artery which in my opinion is the correct explanation for the vascular scalenus syndrome

On the deep surface of this band course the superior intercostal artery and the highest intercostal vein the former at a varying level in relationship to the band. These structures form a good guide in the division of the band, for unless the vein is laid bare the band is not completely divided and mobilisation of the apex in this plane would lead to an extrapleural and not an extrafascial strip

It should similarly be noted that the fascia on the mediastinal aspect of the pleura splits to enclose the internal mammary artery and to ensure that mobilisation be carried out extrafascially the fascia must be divided below the level of the internal mammary

The brachial plexus not infrequently receives a contribution from the 2nd dorsal nerve this contribution varying in importance When it is present, the posterior margin of the second band reaches the level of and tends to be overlaid by the nerve but this gi es rise to no serious difficulty if the anatomical variation is recognised.

The phrenic nerve sometimes and accessory branches more commonly pass superficially to the internal mammary artery which will need added care during the mobilisation

The Operation

Pre-operative Medication Omnopon 20 mg (⅓ grain) and hyoscine 0 4 mg (1/150 grain) is gi en one hour before operation This is supplemented with an intravenous injection of omnopon if necessary

Anaesthesia Local anaesthesia is most commonly used although many operators prefer general anaesthesia The advantages of local anaesthesia are (1) There is less bleeding because adrenaline is added to the anaesthetic solution (2) Breathing is quiet although with modern general anaesthesia similar quiet breathing is obtained. (3) The patient is able to warn the operator when he wishes to cough and by supporting the apex the patient can effecti ely clear the secretions from his bronchial tree (4) The patient s condition for the first twenty-four hours after the operation is appreciably better than after general anaesthesia (5) Lastly an advantage both to the experienced and inexperienced operator is that he must be gentle in his operating, and within reason the length of time taken to complete the operation is immaterial as the anaesthetic will last three hours or more

Local anaesthesia is carried out with a solution of novocain 0 25 per cent and amethocaine 1 200 The patient first lies on his back, and the brachial plexus is infiltrated Some operators omit this but experience shows that in cases so treated

elevation of the scapula is easier and not accompanied by the dull ache which is complained of when the plexus is not blocked

The patient then turns on his side and paravertebral injection of the 2nd to the 5th dorsal nerves is carried out All layers of the line of incision are infiltrated, and intradermal wheals are made for the towel clips

Position on the Table The patient lies in the lateral position A firm chest rest is placed in order to prevent his falling forwards and the pelvis is similarly fixed with supports The chest-rest should not come above the level of the 3rd rib and should not be too bulky as too high a position interferes with the resection of the anterior end of the 2nd rib and too much bulk with the elevation of the scapula the latter is also interfered with by hyperextension of the head

First Stage

Incision The incision is L-shaped, the vertical limb extending from the upper border of the scapula to the level of the 8th rib in the scapular vertebral interval about 1½ inches from the spinous processes The transverse limb of the incision goes forwards to the midaxillary line (Fig 151 *a*) This generous incision allows of free elevation of the scapula which with meticulous haemostasis is essential if all the operative steps are to be carried out under accurate visual control

Skin towels are fixed to the wound edges after the skin and subcutaneous tissue have been divided. The muscles are divided with a diathermy knife the musculo-cutaneous flap raised and the scapula elevated by sharp dissection until the serratus anticus comes into view The lateral branches of the intercostal vessels preferably are ligated The wound margins and the exposed portion of the chest wall are covered with warm moist packs which not only preserve body heat but prevent the tissues getting dry a point of greater importance

The upper margin of the serratus anticus is then defined and separated from the axillary fascia and the upper three digitations of this muscle are then detached from the chest wall with a diathermy knife Dissection if carried out close to the chest wall is practically bloodless and it is then also possible to elevate the whole of the axillary contents from the chest wall without damage the dissection extending forwards under cover of the outer margin of the pectoralis minor muscle If the patient complains of any pain when the lateral cutaneous branches of the intercostal nerves are cut, as occasionally may happen these may be divided with a knife with little discomfort The subscapular area being covered with warm packs the serratus posticus superior is now elevated from its costal attachments and excised This often frees the posterior edge of the scalenus posticus which is elevated detached, and excised The scalenus medius is now in view at its attachment to the posterior end of the first rib By freeing its inner aspect with the finger a pair of scissors can be thrust safely through the substance of the muscle on to the finger which guards the plexus keeping the scissors close to the upper surface of the rib In this way the bulk of the muscle can be detached and a portion of it can be excised (Fig 151 *b*)

The ribs are then resected the number and length of ribs depending on the considerations previously discussed When freeing the periosteum it is essential to free it back on to the neck of the rib not only on its inner but also on its upper and lower surfaces It is then possible to resect the rib well back on the neck by opening the costo-transverse joint with the rib cutter and then swinging the forceps around

the neck of the rib The determined portions of the 2nd and 3rd rib are taken out separately the 1st rib being treated differently

Before commencing the resection, the upper surface of the rib is cleaned with a small swab on a holder and the fascia over the vein is detached, usually by gentle digital pressure this allows the vein to fall away safely while resecting the anterior end of the rib

The periosteum is elevated from the under-surface of the posterior half of the rib so that the inner *margin of the rib comes into view and this margin is then*

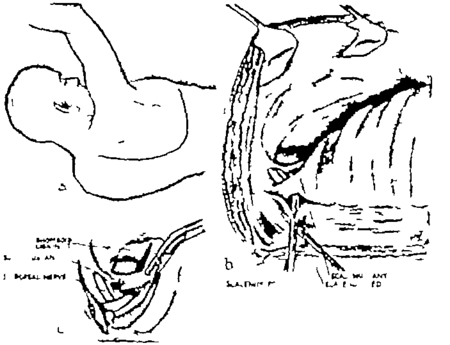


Fig 5

a, Line of incision. Note that it is placed closer to the spinous processes than the vertebral border of the scapula, and is carried forwards well below the inferior angle of the scapula beyond the posterior axillary line

b The scapula has been reflected and the upper part of scalenus anticus detached from the chest wall Scalenus posticus has been detached and a pair of forceps has been thrust through the substance of scalenus medius at its attachment to the 1st rib Scalenus anticus is shown, *but this* muscle normally cannot be seen as it is portrayed

The posterior end of the 1st rib has been removed The anterior portion is drawn downwards to expose the scalenus anticus and the rhomboid ligament both of which can be cut under vision.

cleared With the finger on the inner margin of the neck of the rib to protect the 1st dorsal nerve the posterior part of the upper surface can be cleaned quite safely provided the periosteal elevator is kept close to the bone The rib is now divided under vision about 1 inch from the costo-transverse joint the latter joint is then opened with the rib shears and the posterior end of the rib is levered forwards. Often the whole head and posterior end can easily be avulsed If not the rib neck is *cut by pushing the neck forwards into the jaws of the shears*, the tips of which are in view this manoeuvre ensures that no damage is done to the nerves.

The remainder of the periosteum is now pushed off the under surface of the rib with a small swab on a holder This has an advantage over using a rugine in that only the periosteum on the outer half of the rib is detached the attachment of scalenus anticus remaining undisturbed The back end of this portion is now drawn downwards and forwards with sequestrum forceps and the remainder of the scalenus medius fibres ar cut (Fig 151 c) The scalenus anticus then comes into view and is divided above its attachment which is incidentally linear and may extend practi

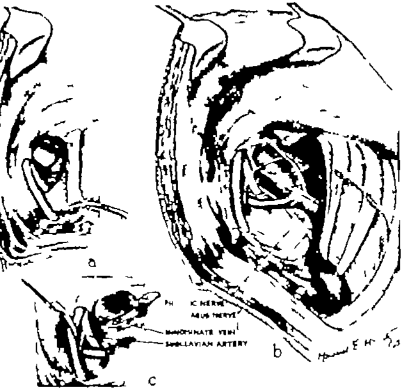


Fig 152

The 1st band of Sebileau and the periosteum of the 1st rib have been divided posteriorly and the 2nd band of Sebileau has been defined

b The right apex has been mobilised from the mediastinum and the vertebral bodies with the mediastinal structures laid bare. The vagus nerve should be covered by layer of fascia and is only visible when the fascial covering is thin

The 2nd band has been divided exposing the superior intercostal artery and the vertebral vein crossing the innominate The 3rd band is ready for division.

cally as far forwards as the costo-clavicular ligament which is now cleared by gently swabbing backwards the innominate vein which is applied to its posterior surface The outer fibres of the ligament are divided, thus enabling the anterior end of the rib to be divided through the costal cartilage The division of the structures on the inner margin of the rib should be done under vision and not blindly if accidents are to be avoided

Apical Mobilisation DIVISION OF THE FIRST BAND OF SEBILEAU The lower margin of the lowest trunk of the plexus is defined by incising the fascia covering it with a

knife Careful blunt dissection in this plane with a pair of forceps will free the first band of Sebileau from the superficial aspect of the nerve so that it can be divided with the periosteum of the 1st rib

DIVISION OF THE SECOND BAND (Fig 152 a) An incision is then made through the fascia over the subclavian artery transversely to its line and blunt dissection with a pair of forceps placed through this incision and parallel to the course of the

Fig 153 The final stage of mobilisation of the apex with resections of the posterior ends of the 4th and 5th ribs.

artery defines the anterior margin of the band Similarly its posterior margin can be defined by inserting the forceps close to the vertebral body The 1st dorsal nerve is gently retracted upwards and the band is divided with a knife or scissors if preferred, until the highest intercostal vein or the superior intercostal artery comes into view Sometimes it may be difficult at this moment to divide the band completely in which case it is wiser to proceed to division of the third band

DIVISION OF THE THIRD BAND (Fig 152 *b*) The remaining fibres of scalenus anticus and the fascia covering it are divided and then the fascia over the innominate vein This exposes the internal mammary artery and the fascia at its lower margin is incised The correct extrafascial plane is now established and by sharp dissection this is cleared downwards and backwards on the mediastinum the correct layer for completion of the di ision of the second band is easy to see in those cases where it has been left

The intercostal muscles arteries and nerves and the periosteum of the 2nd and 3rd ribs are divided and the remainder of the apex is separated from the vertebral bodies and the mediastinum (Fig 152 *c*) It will be found that over the artery especially on the left side the fascia is attached at its lateral margins and when a correct mobilisation has been carried out, the artery vein, and phrenic nerve are laid bare Mobilisation on the mediastinum (Fig 153) can be carried out to the level of the aortic arch or vena azygos major in all cases except when the apex is very soft when it should be more limited The 3rd dorsal nerve is divided as far back as possible because it is difficult to anaesthetise it at the second stage Where the apex is very solid and as is usual in these cases the cavitation is extensive segments of the posterior ends of the 4th and 5th ribs, about 2 inches long, should be removed and mobilisation be carried out as far as the lung root. After assurance that haemostasis is satisfactory the wound is closed using a single row of interrupted sutures for the muscles and interrupted sutures for the skin When the apex is soft, 3 to 4 ounces of saline are left in the subscapular space thus to limit the degree of paradoxical movement of the apex in the immediate post-operative phase

Second Stage

Pre-operative medication and anaesthesia are similar to that for the first stage except that brachial plexus anaesthesia is not employed, and the 4th to 8th dorsal nerves are anaesthetised

The original wound is reopened after excision of the old skin scar as this enables a more satisfactory suture to be made

The scapula is again reflected and the subscapular space is deliberately reopened The determined number and length of ribs are resected and the lung is remobilised. Personal experience suggests that in practically every case remobilisation should be carried out at the second stage failure to do this leads to disappointment, in that too high a percentage of ca ities fail to close

Where small resections have been practised or where a dorsal lobe cavity is present, remobilisation is essential In the latter group it may be necessary to carry the mobilisation down to the 8th or 9th rib

When the cavities are small and situated high in the apex, it may be sufficient only to detach the 3rd intercostal bundle and divide the periosteum of the 4th rib but generally it is wiser to mobilise down to the level of the 6th rib posteriorly Remobilisation should be commenced by division of the periosteum of one of the newly resected ribs then by gentle blunt dissection the extrafascial plane can be entered and the intercostal muscle and the neuro-vascular bundle be safely di ided. In this way the mobilisation can be done from below upwards and the configuration of the apex on the mediastinum can be determined more accurately By the time the second stage is undertaken the extrafascial space is lined by a smooth membrane

which is firmly fixed to the lung and mediastinum and when the apical level has been determined this membrane can be incised and the apex further liberated. Any downward extension of the mobilisation can be carried out easily once the proper plane has been opened

Third Stage

Premedication and anaesthesia are as for the other stages the appropriate dorsal nerves being anaesthetised

The lower part of the original incision with its forward extension are reopened and an extra incision is made extending downwards and slightly backwards from the angle of the main incision in order to give access to the 8th 9th and 10th ribs which are exposed and lengths of their posterior ends resected

a *b*

Fig 54. Miss V B aged 25

a X-ray showing pre-operative condition of collapsed right upper lobe Two cavities.
b X ray showing same patient two and one-half years following right upper thoracoplasty Symptom free Quite fit and well

After each stage of the operation the wound is dressed After the wound has been covered with gauze firm bands of adhesive strapping are applied extending across the midline both anteriorly and posteriorly this fixes the ribs which have been resected and thus limits paradoxical movements A final covering of cotton wool is kept in position with a many tailed bandage The former should be generous in amount as a cushion to the wound on which the patient of necessity has to lie The bandage should be loose so that the movements of the sound side are not hampered

Pre-operative Care

Apart from the care given to all patients prior to operation, certain specific problems arise in this type of case

These patients are particularly liable to scoliosis in fact, every patient has a

certain degree of this deformity especially in the upper dorsal spine. This tendency can be easily understood from the nature of the operation. The lateral stays of the vertebral column are seriously interfered with and when apical mobilisation has been performed, the costal attachments of the iliocostalis are completely lost. The degree of scoliosis is further increased by the patient's faulty position and to a great extent this can be minimised by *Postural Exercises* which preferably should be carried out by a trained physiotherapist. These exercises are of most importance in the post-operative phase but experience has shown that the best results are obtained when the patient has been educated as to what is expected of him before the operation is undertaken, hence it is wise to institute them for at least ten to fourteen days before the operation.

b

Fig. 55. Miss G. J., aged 22. Two years' history of pulmonary tuberculosis on admission to hospital.

X-ray showing the giant cavity occupying the upper part of the chest with infiltration of lower lobe below. General condition good. BSR 68. This had remained at this level for past six months. Nov. 6, *1945*, 1st stage thoracoplasty. 1st, 2nd and 3rd ribs and posterior ends of 4th and 5th removed. Mobilisation to level of aortic arch. An axillary thrombosis delayed 2nd stage for one month. Dec. 6, *1945*, 2nd stage thoracoplasty. Remainder of 4th and 5th ribs and 6th, 7th, and 8th ribs removed. Posterior part of apex detached. Dec. 20, *1945*, 3rd stage thoracoplasty. Small portions of 9th and 10th ribs removed. Post-operative course uneventful.

b. X-ray showing post-operative state. *Sept. 10, 1948.* Patient reported fit and well. Leading normal life. No cough or sputum. No evidence of activation.

Breathing Exercises are valuable but pre-operatively should be undertaken with the greatest circumspection. The exercises are directed towards diaphragmatic movements and should not be undertaken pre-operatively in toxic or unstable cases.

Cough. Many patients waste a great deal of energy in unproductive cough. In the main, patients who arrive at the stage when thoracoplasty is contemplated have learned the technique of cough so that only when sputum can be raised is the effort made. The patient should be encouraged if possible to find the position in which the sputum is most easily raised; often it is then possible to render the patient free from sputum for many hours at a time. In consequence the patient, by adopting

this position before coming to the theatre can empty his secretions for the period of the operation

Oxygen The possible need for oxygen post-operatively should be explained and the patient should practise the use of an oxygen mask and/or oxygen spectacles

Blood Transfusion should be resorted to pre-operatively in all cases in which the haemoglobin is low and in lesser degrees recourse should be had to haematinics.

Post-operative Care

The patient is returned to his bed in the theatre The sitting position is preferable, as in this position respiration and coughing are easier If general anaesthesia has been used or there is any degree of shock the patient will be better lying flat

The following points need special emphasis

Oxygen Therapy There should be no hesitation in resorting to the use of oxygen. Obvious respiratory distress will of necessity be an indication but many minor degrees of oxygen lack tend to be overlooked A persistent tachycardia not infrequently is an indication of such a lack as shown by the decrease in the pulse rate after the administration of oxygen

Cough In the immediate post-operative phase, coughing is difficult because of the pain the tendency toward paradoxical movement of the chest wall and the viscidity of the sputum

Pain should be controlled if necessary with morphine in the first forty-eight hours usually however veganin 0 65 gm (10 grains) is sufficient. When morphine is used doses not exceeding 10 mg ($\frac{1}{6}$ grain) are preferable to larger quantities which may abolish or dull the cough reflex The withholding of analgesics will inevitably lead to the suppression of cough

Paradoxical movement has to a great extent been controlled by the strapping of the chest However it is a great help to the coughing patient if the upper part of the chest below the clavicle is supported, either by the nurse s or the patient s own hand

Secretions can be rendered less viscid by the use of expectorants either a saline expectorant in hot water or ammonium carbonate in milk is useful Efficient expectoration of secretions is the most efficient prophylactic for the commonest post-operati e complication, atelectasis

Vomiting occurs frequently to a mild degree irrespective of the type of anaesthesia used Serious vomiting bears a direct relationship to the amount of fluid ingested The cutting off of fluid by mouth for a few hours and its substitution wi h rectal or more rarely intravenous fluids will in ariably cure it, but the patient should limit himself to frequent small sips when recommencing to take fluids by mouth.

Postural Exercises These exercises are commenced twenty-four hours after the operation They include arm and scapular movements and the correction of faulty posture At first *passi e movements* are carried out with encouragement to the patient to perform acti movements as soon as possible After the second stage, scapular movements are not started until about one week after the operation, as movements earlier than this predispose to the slipping of the scapula over the upper most unresected rib after a week the scapula has formed a bed for itself to which it easily returns after it has been abducted

Correction of the spinal posture must be effected by the conscious effort of the patient It is easy for the patient to consider a faulty position as being normal if it is maintained for a sufficient length of time In consequence it is valuable in the early days of treatment to place a large mirror at the end of the patient s bed so that he can isually correct his deformity

Later the exercises become more vigorous and muscle development of the trunk and legs is encouraged

In satisfactory cases and the majority are so the movements of the arm and shoulder girdle on the operated side are normal or practically so and when the patient is dressed little or no deformity should be obvious

The patient remains in bed for three months after the operation This period of rest ensures that the functional stenosis of the bronchi draining the cavity resulting from the relaxation procedure can become organic and that the patient s resistance has full opportunity to heal or arrest his disease It must be appreciated that in the ultimate analysis it is the patient and not the surgeon who cures the disease

Blood Transfusions Transfusions are rarely needed as an immediate post-operati e measure if local anaesthesia is used as blood loss is not great. Their use between stages however i aluable not only to raise a reduced haemoglobin but as an aid to the patient s general condition and resistance

Accidents o the Operation

Accidents in the main are avoidable but under circumstances of difficulty when the apex is hard and there is a great deal of peripleuritis they are unavoidable but do not lead to untoward results if they are efficiently handled.

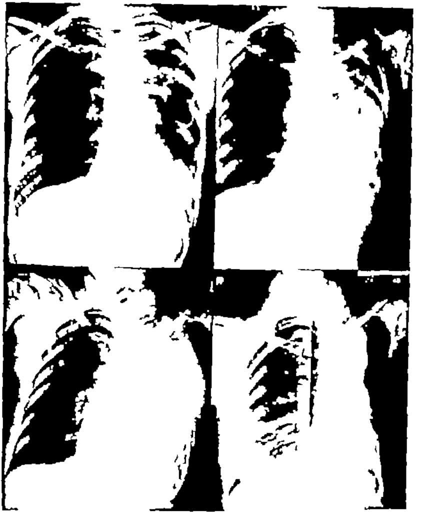
Opening of the Cavity This is the most serious accident If an extrafascial operation is practised, the risk is negligible in cases in which the apex is soft but in old-standing cases the cavity may ulcerate on to the ertebral bodies and may inevitably be opened when the area is being mobilised, generally with a knife

Should the ca ity be opened, the contents should be cleaned out and the cavity lightly packed Mobilisation of the apex should be continued until the area below the cavity has been well liberated which may entail the resection of the posterior ends of one or two further ribs The edges of the opening are excised and the opening is closed with three layers of suture which is again reinforced with a portion of the intercostal muscle if this is possible

When the apex is hard the resection of the ribs can be carried down to the 7th and this will preclude the necessity for reopening this part of the wound. If this extension of the resection is deemed inad isable care should be exercised at the second stage which should be delayed three or four weeks in order to avoid opening the subscapular space Before the wound is closed after the ca ity has been sutured, a gram of streptomycin should be left in the space

Opening of the Pleura This may happen when the pleura is thin, the commonest site being anteriorly on the mediastinal aspect. If an opening is made further mobilisation should be continued until the area of the opening is lax If the opening is large it should be closed with a fine suture If small it is more satisfactorily closed by ligature after the area has been closed with a pair of haemostats this prevents puncturing the pleura with a needle which may give rise to pin point leaks At the

b



d

Fig 56 Mrs M. C aged 34 Diagnosed pulmonary tuberculosis four and one-half years before admission to hospital having been t bed rest during this period. On admission, running pyrexia t 00° °F Sedimentation rate 60 Further bed rest for four months.

a, X-ray shows extensive cavitation in all zones of left lung with some infiltration of right apex. *May 12 1945* st stage thoracoplasty w th resection of st 2nd and 3rd ribs and mobilisation of the apex Following this, atelectasis of whole of left lung with recurrence of pyrexia which did not settle for about four months.

b, X ray at this time shows collapsed left lung with cavity still persisting and regeneration of 2nd and 3rd ribs *Nov 15 1945* 2nd stage thoracoplasty Resection of regenerated portions of 2nd and 3rd ribs and of the 4th rib Remobilisation of apex was carried out down to level of aortic arch Immediately following operation temperature rose to °F Pulse 3 Wound was bulging and scapula riding on fluid.

c, X-ray shows extrafascial spac to be nearly full and the scapula to be pushed outwards by the fluid Aspiration of the space demonstrated that fluid contained hyle *Nov 27 1945* (i.e twelve days fter 2nd stage) 3rd stage thoracoplasty Extrafascial space was found to be filled with a coagulum which was whit olou rathe like lotted milk. This was removed and segments of

end of the operation air should be removed from the pleura with an artificial pneumothorax apparatus using an initial needle If the air is left in the pleura it often leads to an unnecessary physiological disturbance

Vascular Accidents The innominate vein may be opened more especially while performing re-operation The bleeding should be controlled by digital pressure or with a small gauze swab on forceps while the vein is freed above and below the site of the opening sufficiently to allow of the application of a clamp preferably a modified type of Trendelenburg clamp After its application the opening can be closed with a running Lembert suture

The subclavian artery may have to be tied as was the case when a ligature on the superior intercostal artery sheered through close to the main artery; since this accident the superior intercostal has always been ligated a little distance from the parent trunk Ligation of the subclavian artery at this level leads to no complication

Nerve Injury Injury to a nerve should not occur with reasonable care and certainly not if resection of the ribs and mobilisation of the apex are carried out under direct visual control

Damage to the Thoracic Duct The thoracic duct has not infrequently been damaged Sometimes the accident is noticed at the time but it may not be recognised until later The escape of chyle into the space is often the first evidence of the damage If it is recognised at the time the damaged duct is found and ligated the clue to its position being the issuing of chyle which pumps out synchronously with the respiratory movements If the condition is unrecognised, the syndrome is nearly classical. The patient runs an immediate post-operative temperature of 101 to 102 F and x rays taken forty-eight to seventy two hours after operation show a large collection of fluid in the extrafascial space the space sometimes being quite full and the scapula occasionally floating Aspiration of the space at this time reveals blood-stained fluid which may be reported as blood-stained pus or the wound may rupture discharging fluid with immediate remission of the temperature and the fluid may be reported again as pus The patient s condition, however is so good that it would be most unlikely that an infection of such a large tissue space could be present in a degree severe enough to produce pus of such quantity in so short a time If this complication is kept in mind the addition of a little ether to the fluid clearly demonstrates that the cloudiness is due to fat.

Late recognition occurs seven to ten days after the first stage and if the patient s condition will allow the second stage should be proceeded with and the duct recognised and ligated If not the wound should be dressed with a penicillin-sulphathiazole powder and parenteral penicillin should be given until such time as the second stage safely can be undertaken

More rarely chyle may be found in the extrafascial space quite unsuspectedly

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the 5th 6th and 7th ribs were excised. The bone was detached posteriorly and the hole in the thoracic duct was identified The duct w tied abov and below this site The course following this stage was uneventful *Jan. 30 1946* 4th stage thoracoplasty Segments of the 8th, 9th, and 10th ribs were resected While resecting the 9th rib small empyema pocket was opened. Pus collected from this spac proved t be sterile Temporary tube drainage into space was established for about four days, the whole area healing practically by first intention

d X-ray show final condition.

without evidence of damage to the duct In these circumstances fluid does not re-collect after the second stage.

Post-operative Complications

The majority of the post-operative complications can be avoided if the points in the technique of the operation and post-operative care are rigidly observed

Atelectasis is the most common complication and it may be simple or infected.

Simple Atelectasis The proclaimed incidence of this complication varies according to the care and frequency of the post-operative clinical and radiological studies carried out. The atelectasis may be evanescent and last only a matter of hours and so be missed completely In this type there is little or no constitutional disturbance and in the great majority of cases the condition clears up in less than a week. If the condition is recognised the patient should be encouraged to cough while lying flat on the sound side This should be done three or four times daily and with intelligent nursing can be carried out in seriously ill patients without great disturbance

Infected Atelectasis occurs much less frequently There are usually serious constitutional disturbances. The temperature pulse and respirations are raised cough and sputum increase the appetite is poor and the patient feels and looks ill In these cases it is most important that the patient should raise his secretions and if postural treatment does not prove immediately effective bronchoscopic aspiration should be carried out. Chemotherapy with penicillin and sulpha drugs should be instituted. If the condition does not respond in three or four days a short course of streptomycin should be given. A short course advisedly is recommended as prolonged exhibition of this drug is to be avoided at this stage since the object at this juncture is to control the secondary infection and not the tuberculous infection. Persistence with streptomycin may induce resistance in the tubercle bacillus, a most unfortunate outcome for streptomycin may later be needed to control a tuberculous spread

The majority of cases react to the relatively simpler forms of treatment, but occasionally the condition may go on to abscess formation or even a fatal termination

Lung Abscess is extremely rare In two cases however its recognition was followed by drainage with satisfactory healing and the completion of the thoracoplasty

In all cases in which radiological atelectasis persists for three weeks even though there are no constitutional disturbances it is wiser to continue with the thoracoplasty and collapse the base Only small resections are necessary in the lower three ribs If this is not done there is considerable risk of cavitation occurring in the lower lobe at a later date and this is a much more serious problem for treatment It is interesting to note that in a high percentage of such cases calcifications appear in the lower lobe two to three years after operation, evidence that tuberculous lesions were present in the situation resulting from the atelectasis

Tuberculous Spread Reactivation of pre-existing foci must be excluded before it can be definitely established that actual spread has taken place It will be found in quite a high percentage of cases on examining the pre-operative films that a lesion was present at the site of the apparently new lesion of which it is in fact an extension Fresh lesions however do occur and are an indication that further active treatment must be delayed These lesions react well to streptomycin, provided resistance to the drug has not been previously acquired If streptomycin is not

available Injections of one of the gold preparations will often stabilise the patient and induce retrogression of the lesion. Small doses of about 0 005 mg once a week are all that is necessary larger doses rarely give better results

Infection of the Extrafascial Space The infection may be pyogenic or tuberculous

PYOGENIC INFECTION Pyogenic infection is due to faulty aseptic technique during the operation The success of treatment will depend on its early recognition The general toxic signs of infection are present—raised pulse and temperature Physical signs may be misleading in that there may be absent breath sounds over the base on the operated side a not infrequent finding even when there is no pulmonary complication present being due to the deficient movement of the chest on this side On clinical grounds a diagnosis of an infected atelectasis is most often made Radiographs however usually give the clue to the diagnosis in that they show a ballooning of the extrafascial space

This ballooning of the extrafascial space may be appreciated clinically in certain cases the infraclavicular hollow being fuller than it should be and an abnormal fullness in the axilla being present, the latter finding being the more common Later if the condition is not recognised oedema and redness of the anterior chest wall and breast may occur but it must be stressed that in the early phases there is no evidence of either oedema or redness Ballooning of the space may occur also from haemorrhage from leakage from the thoracic duct already referred to and in some cases it may result from an excessive amount of a simple transudate

The only method of determining the cause of this ballooning is by aspiration of the contents of the space This must be done under strictly aseptic precautions Before actual pus formation has occurred suspicion of infection is based on the character of the fluid withdrawn which incidentally is always blood-stained when infection has occurred the fluid has a purplish colour and if this is the case local and parenteral penicillin therapy should be commenced forthwith a specimen of the fluid being submitted for bacteriological examination and culture

When pus has formed it is doubtful whether chemotherapy alone will lead to successful control of the infection and it is preferable to institute drainage as soon as possible A catheter is introduced through a cannula which has been inserted into the axilla, and the tube is attached to a suction apparatus parenteral penicillin being administered meanwhile

Early aspiration and drainage are essential because delay will inevitably lead to rupture of the back wound and this will further complicate the treatment This accident necessitates delaying the second stage for a month. At the time of the second stage care is taken not to reopen the extrafascial space and this is facilitated by a further extension of the horizontal limb of the incision forwards and upwards for a few inches to allow of a free elevation of the lower part of the scapula The upper unresected ribs are excised to permit the scapula to bed forwards thus decreasing the size of the space and facilitating its closure. Cases treated on these lines heal without trouble

TUBERCULOUS INFECTION Tuberculous infection of the space is one of the most serious complications of the operation It arises either from damage to the lung itself or from the lymphatic glands, the latter undoubtedly being the commoner Glands removed at operation all show either frank tuberculosis or interestingly enough sarcoid changes During the operation if there is any suspicion that the vascular

supply to a gland has been damaged it is safer to remove the gland, but otherwise the gland should not be interfered with. Tuberculous infection rarely manifests itself earlier than three or four weeks after the operation, and then commonly by rupture of the contents of the space through the wound. Prior to the introduction of streptomycin the condition was quite intractable but if streptomycin therapy is instituted as soon as the infection is recognised the results are gratifying. Injection of streptomycin into the space only has sufficed in one or two cases but if streptomycin is in free supply it is better to combine the topical application of 0.5 gm.

a b

Fig. 157. Miss E. M. D., aged 38. *Jan. 4, 1945.* Patient admitted to hospital with contralateral artificial pneumothorax.

a, X-ray shows large suspended cavity. Fluid level in pleura. Thoracoscopy—adhesions not cauterisable. Fluid turbid but does not contain bacilli. Sterile on culture. Decided to abandon artificial pneumothorax. Lung failed to re-expand. Fluid began to become more purulent. Thoracoplasty decided upon. *May 10, 1945*, 1st stage left thoracoplasty: 1st, 2nd, and 3rd ribs removed. No mobilisation performed. Beds of ribs formalinised. *May 29, 1945*, 2nd stage thoracoplasty: Resection of 4th, 5th, 6th, and 7th ribs. *June 14, 1945*, 3rd stage thoracoplasty: Resection of 8th, 9th, 10th, and 11th ribs. Cavity became much smaller following this intervention and pleural space obliterated. After period at sanatorium, patient's general condition improved. Sputum still continued to be positive. *June 8, 1948.* Patient readmitted to hospital. *June 22, 1948*: Revision of left thoracoplasty under streptomycin cover. Regenerated portions of 2nd, 3rd, 4th, 5th, 6th, and 7th ribs resected. Lung apex mobilised down to the aortic arch and 6th rib posteriorly. Post-operative course without incident. *Jan. 14, 1949.* Patient very well. Slight cough and mucoid sputum which is negative.

b, X-ray shows no evidence of cavitation.

daily into the space with intramuscular injections of 0.5 gm. twice a day. About one month's treatment usually suffices.

Careful follow-up of these cases is essential in order to ascertain whether or not the desired result has been achieved. Failure to close the cavity may entail a further operation with remobilisation of the apex. This is a difficult procedure but is usually followed by satisfactory results (Fig. 157).

Observation of the contralateral lung is also essential. In a small percentage of cases a bilateral thoracoplasty may be necessary to stabilise the disease (Fig. 158).

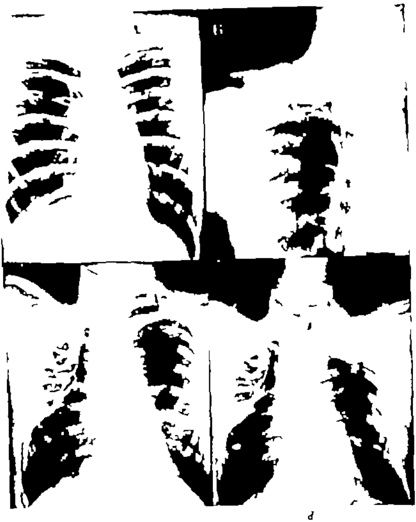


Fig. 58 M. W. J. S. aged 26 *Jan. 9 1942* Admitted to hospital with two years' history of pulmonary tuberculosis.

X-ray shows cavitation right apex with infiltration left apex. Tomographically no evidence of cavitation at left apex.

b Tomograph shows cavity at right apex. *Jan. 22 1942* 1st stage right thoracoplasty Resection of 1st, 2nd, and 3rd ribs with apical mobilisation *Feb. 5 1942* 2nd stage thoracoplasty Resection of 4th, 5th, 6th and 7th ribs. Further mobilisation of apex to level of 7th rib posteriorly Post-operative course uneventful. Discharged with trace of negative mucoid sputum. Patient remained fit and well until March 27 1947 Sputum became positive No evidence of cavitation however was established until Nov. 12, 1947 when a small cavity was found at left apex.

X-ray shows small cavity left apex Right upper thoracoplasty Left phrenic crush was advised. Patient was discharged home for bed rest. *June 26, 1948* Re-admitted to hospital for further bed rest Bronchoscopy showed no evidence of tuberculous bronchitis. *Oct. 28 1948* 1st stage left thoracoplasty Resection of 1st and 2nd ribs and posterior end of 3rd Extrafascial apicolysis to under cover of 4th rib *Nov. 9 1948* Anterior end of 3rd rib and 4th and 5th ribs removed Mobilisation down to level of upper border of 6th rib. Post-operative course smooth except for small area of infection of the wound Three months after operation patient fit and well No cough and sputum

d X-ray shows condition following bilateral thoracoplasty

The results of thoracoplasty in our hands are shown in the tabulation

Results of Thoracoplasty

Total number of cases (treated in two institutions)		518
Early mortality (patients unable t leave hospital).		55 ([illegible] 6%)
Number of Cases followed up		421
Cavity closure and sputum negative or no sputum		338 (89 5%)
Cavity unclosed or sputum positive		4 ([illegible] 5%)
Late mortality	before one year (8)	42 (9 [illegible]%)
	after one year (34)	
Cases insufficiently followed up		6
Cases operated on less than one year ago		36

II OPERATIONS EMPLOYING AN ARTIFICIAL STOMA

EXTERNAL CAVITY DRAINAGE

Two types of external drainage have been devised one based on the work of Monaldi in which drainage is obtained by the introduction of a tube into the cavity and the other in which drainage is secured by laying the cavity widely open as in the treatment of acute lung abscess

The probable explanation of the value of the treatment is that external drainage decreases the tension within the cavity and in consequence the blood supply to the cavity wall improves so that if the patient s resistance against his disease is good, the disease in the cavity wall is arrested or may even heal The objection to the treatment, as a definitive form of therapy is that it takes no cognisance of the draining bronchi However attempts have been made to produce stenosis of the bronchi with chemical agents or to eradicate the bronchial disease by topical applications of streptomycin If either of these latter objects can be achieved then the prospect of permanent cavity closure should be reasonably good

This form of treatment is only suitable for cavities unassociated with gross parenchymal disease and preferably when the cavities are solitary although Monaldi has treated many cases with two or more cavities each cavity being subject to drainage The most dramatic results are achieved in the distension cavities

The immediate effects of drainage are the decrease in cough and sputum, and, when tube draining has been used the decrease in the size of the cavity as seen on the radiographs

The Technique of Tube Drainage (Monaldi)

Localisation of the Cavity Accurate localisation of the cavity either by radioscopy or by means of antero-posterior and lateral radiographs is essential If possible the operation should be done under radioscopic control although this is by no means essential certainly if the cavity is a large one

Induction of an Artificial Pneumothorax Before the operation is undertaken it is necessary to attempt the induction of an artificial pneumothorax and this should be done over the site to be used for the introduction of the tube It is safer to make a similar attempt also in the interspace above and below that selected. If a pneumothorax can be induced after about 50 c c have been introduced 5 minims of a 10 per cent solution of silver nitrate is introduced into the pleural cavity and the air is promptly aspirated The patient then lies prone for as long as possible during

the next twenty-four hours This solution causes a chemical pleuritis with a resultant pleural symphysis the latter being an essential prerequisite to the introduction of the tube The introduction of a tube into the cavity across a free pleura will almost inevitably lead to an empyema

Resection of Rib Ends Some surgeons advocate the resection of the anterior ends of the 1st and 2nd ribs before proceeding to the insertion of the tube the advantage being that the adhesions between the two surfaces of the pleura occur as a result of the resection and secondly the area of the tube track need not be interfered with when a thoracoplasty is undertaken later

Anaesthesia The operation is done under local anaesthesia, infiltration of the chest wall only in the line of introduction being sufficient

Position of Patient The patient lies flat on his back and some workers advise that the head be at a slightly lower level in case of air embolism

Site of Puncture The site of puncture is chosen after careful scrutiny of the radiographs or radioscopically For cavities in the apex of the lung it is wise to make the puncture in the second intercostal space in view of the probable necessity of a thoracoplasty later because this will place the track below the 2nd rib and a normal apicolysis then can be carried out without interfering with the drainage track If the anterior ends of the 1st and 2nd ribs have been resected previously this precaution will be unnecessary but it should be noted that pre ious resection considerably limits the mobilisation of the apex

Armamentarium Instruments essential to Monaldi s operation include a needle like an artificial pneumothorax refill needle about 12 cm long with an accurately fitting stilette and with centimetre markings on its surface A fine trocar and cannula, through which the tube is inserted is also required. The trocar is so made that its head fits the cannula accurately It has a groove on its side which extends under cover of the cannula so as to allow of free entry of air into the body of the cannula the shaft of the trocar is of smaller calibre than the head and is fixed to a good-sized handle the trocar can be locked into the cannula with a bayonet lock. The cannula itself is also graduated in centimetres and has a lateral ent at its proximal end for attachment to a pneumothorax apparatus It is also possible to get cavernoscopes to fit the cannula, to enable inspection of the cavity walls to be carried out Tubes which will pass easily through the cannula are set with lateral catheter eyes and others with terminal holes Each type can conveniently have marks indicating the length of the cannula

Insertion of Needle into Cavity After the track has been infiltrated and the absence of a free pleural space again has been verified the long needle is inserted through the lung into the ca ity along the line as judged by the radiographs, or under direct radioscopic control Usually the resistance of the cavity wall can be felt but the only certain proof that the needle is in the cavity is the respiratory excursion of the manometer Generally it will be found that the pressures within the cavity are on mean positive side e g minus 4 to plus 6 cm. Introduction of a small quantity of air into the cavity will increase the mean positive readings but after some minutes wait these readings return to the original level

Introduction of the Cannula and Tube The direction and depth to which the needle has been inserted are carefully noted and the needle is withdrawn A small incision is made through the skin and the deep fascia to enable the trocar and cannula to be

inserted easily and they are then pushed along the track in the same direction as the needle the cannula being in communication with the manometer It will be noticed that the manometer registers a slightly positive pressure during the introduction until the cavity is reached and then the same respiratory ariations are noted If the cavity is not reached at the same depth as with the needle it should be advanced another centimetre or so because its larger bulk may deform the wall without perforating it If this fails to enter the cavity or it is seen radioscopically that the direction is wrong, the instrument must be withdrawn to the level of the pleura

b

Fig 59 Mrs B. F aged 16 *April 1942* Admitted to hospital with short history of lassitude, diarrhoea, and omiting Diagnosed as pulmonary tuberculosis. Strict bed rest instituted. X-ray show cavity in right upper zone with scattered infiltration and infiltration of lower and middle zone on left side BSR 8 *May 4, 1942* Left artificial pneumothorax induced. *July 24, 1942* Right artificial pneumothorax induced, latter being grossly contraselective and abandoned forthwith *Nov 24 1942* Monaldi drainage of right apical cavity instituted.

X-ray show ondition of cavity after three months drainage *March 4, 1943* 1st stage thoracoplasty with apical mobilisation, st and 2nd ribs and small portion of 3rd rib resected. *March 18 1943* 2nd stage thoracoplasty Further resection of 3rd and 4th ribs and small portion of 5th rib Remobilisation down to le l of 6th rib *April 8 1943* 3rd stage thoracoplasty Resection of remainder of 5th rib and 6th and 7th ribs. Post-operative course uneventful except for stitch abscess in wound Five years later patient ery well. No cough or sputum. No evidence of cavitation.

b X-ray show left lung fully expanded Right side after thoracoplasty

before reintroducing it no attempt should be made to push the cannula laterally firstly because it will be doomed to failure and secondly because haemorrhage may result from such an attempt When the cavity has been entered cavernoscopy if desired can be carried out or the tube can be inserted into the cavity A generous length of the tube should be inserted into the ca ity beyond the mark on the tube so that it coils up in the ca ity thus ensuring that it will not be pulled out on withdrawing the cannula It is wiser to lea e the tube thus coiled in the ca ity for the first fi e or six post operative days by which time there will be a well-established track No harm comes from such coiling

After withdrawal of the cannula the tube is fixed to the chest wall with strapping or by means of a specially designed shield

Accidents of the Operation AIR EMBOLISM This has already been referred to This must be an uncommon complication and has not been personally encountered should it occur the operation must be abandoned The risk of a fatality is comparable to the risk when an embolism occurs during artificial pneumothorax treatment

HAEMORRHAGE This is not uncommon although it is rarely serious Generally it is small in amount a blob or two of blood being expectorated This need not necessarily lead to the abandonment of the attempt unless the patient is psychologically upset by the incident but should the bleeding be more than minimal the procedure should be postponed

Post-operative Care During the immediate post-operative period great care is necessary to see that the tube remains patent, especially if there is much coughing Failure to take this precaution leads to the expression of the cavity contents along the track into the fascial planes of the chest wall with a resultant cellulitis

Four to five hours after the tube has been inserted it is attached to a suction pump and the cavity is subjected to a negative pressure of 5 to 6 cm of water and this is carried on for eight to ten hours of the day Monaldi suggested periods of intermittent suction and this may explain his being able to claim results far superior to other workers

Bacteriological examinations are carried out at intervals on the aspirated discharges and it will be seen that after about one month of treatment, tubercle bacilli disappear from the discharges, and other organisms which hitherto are absent in all cases appear in the discharge

When there is no cavity obvious in the plain radiographs lipiodol is injected into the tube and it will be seen that the bronchi are still patent Should the tube be accidentally removed from the cavity during treatment it should be replaced as soon as possible This is most easily done by re-introducing the cannula again but this time fitted with an olive-headed obturator instead of the trocar The weight of the cannula is usually sufficient to carry it into the cavity and no force should be used If the latter is at all necessary it is better to use the pointed trocar in the cannula and under radioscopic control If and when the tube needs changing, the new tube can generally be introduced easily but if not the above technique can be used.

The results of this form of treatment have been disappointing in this country in that it has failed as a single form of treatment to close the cavity except in a small percentage of cases Removal of the tube when the cavity has been reduced to merely a track, has resulted in the reappearance of the cavity In consequence it is almost a routine practice to follow the period of drainage with a thoracoplasty There is some divergence of opinion as to the type of thoracoplasty to be undertaken some workers advocate a lateral thoracoplasty only but it seems logical to assume that a relaxation procedure is necessary in order to close the still patent bronchi In consequence it is my practice to carry out an extrafascial mobilisation with the thoracoplasty

More recently modifications of the Monaldi technique have been introduced the most notable being that of Maurer who by dilating the track with specially

inserted easily and they are then pushed along the track in the same direction as the needle, the cannula being in communication with the manometer It will be noticed that the manometer registers a slightly positive pressure during the introduction until the cavity is reached and then the same respiratory variations are noted. If the cavity is not reached at the same depth as with the needle it should be ad anced another centimetre or so because its larger bulk may deform the wall without perforating it If this fails to enter the cavity or it is seen radioscopically that the direction is wrong, the instrument must be withdrawn to the level of the pleura

b

Fig 59 Miss B. F aged 6 *April 1942* Admitted to hospital with short history of lassitude diarrhoea, and omiting Diagnosed as pulmonary tuberculosis. Strict bed rest instituted X-ray show cavity in right upper zone with scattered infiltration and infiltration of lower and middle zone on left side BSR 8 *May 4 1942* Left artificial pneumothorax induced *July 24, 1942* Right artificial pneumothorax induced latter being grossly contraselective and abandoned forthwith. *Nov 24 1942* Monaldi drainage of right apical cavity instituted.

a, X-ray show condition of cavity after three months drainage *March 4, 1943* 1st stage thoracoplasty with apical mobilisation 1st and 2nd ribs and small portion of 3rd rib resected. *March 18 1943* 2nd stage thoracoplasty Further resection of 3rd and 4th ribs and small portion of 5th rib Remobilisation down t level of 6th rib *April 8 1943* 3rd stage thoracoplasty Resection of remainder of 5th rib and 6th and 7th ribs. Post-operati course uneventful except for stitch abscess in wound. Fi years later patient ery well No cough or sputum. No evidence of ca itation

b X-ray show left lung fully expanded Right side after thoracoplasty

before reintrodu ing it no attempt should be made to push the cannula laterally firstly because it will be doomed to failure and secondly because haemorrhage may result from such an attempt When the cavity has been entered cavernoscopy if desired can be carried out or the tube can be inserted into the ca ity A generous length of the tube should be inserted into the cavity beyond the mark on the tube so that it coils up in the ca ity thus ensuring that it will not be pulled out on withdrawing the cannula It is wiser to lea e the tube thus coiled in the ca ity for the first fi e or six post-operati e days by which time there will be a well-established track No harm comes from such coiling

After withdrawal of the cannula the tube is fixed to the chest wall with strapping or by means of a specially designed shield

Accidents of the Operation AIR EMBOLISM This has already been referred to This must be an uncommon complication and has not been personally encountered should it occur the operation must be abandoned The risk of a fatality is comparable to the risk when an embolism occurs during artificial pneumothorax treatment

HAEMORRHAGE This is not uncommon although it is rarely serious Generally it is small in amount a blob or two of blood being expectorated This need not necessarily lead to the abandonment of the attempt unless the patient is psychologically upset by the incident but should the bleeding be more than minimal the procedure should be postponed

Post-operative Care During the immediate post-operative period great care is necessary to see that the tube remains patent especially if there is much coughing Failure to take this precaution leads to the expression of the cavity contents along the track into the fascial planes of the chest wall with a resultant cellulitis

Four to five hours after the tube has been inserted it is attached to a suction pump and the cavity is subjected to a negative pressure of 5 to 6 cm of water and this is carried on for eight to ten hours of the day Monaldi suggested periods of intermittent suction and this may explain his being able to claim results far superior to other workers

Bacteriological examinations are carried out at intervals on the aspirated discharges and it will be seen that after about one month of treatment, tubercle bacilli disappear from the discharges and other organisms which hitherto are absent in all cases appear in the discharge

When there is no cavity obvious in the plain radiographs lipiodol is injected into the tube and it will be seen that the bronchi are still patent Should the tube be accidentally removed from the cavity during treatment it should be replaced as soon as possible This is most easily done by re introducing the cannula again, but this time fitted with an olive-headed obturator instead of the trocar The weight of the cannula is usually sufficient to carry it into the cavity and no force should be used If the latter is at all necessary it is better to use the pointed trocar in the cannula and under radioscopic control If and when the tube needs changing the new tube can generally be introduced easily but if not the above technique can be used

The results of this form of treatment have been disappointing in this country in that it has failed, as a single form of treatment to close the ca ity except in a small percentage of cases. Removal of the tube when the cavity has been reduced to merely a track, has resulted in the reappearance of the ca ity In consequence it is almost a routine practice to follow the period of drainage with a thoracoplasty There is some di ergence of opinion as to the type of thoracoplasty to be undertaken some workers advocate a lateral thoracoplasty only but it seems logical to assume that a relaxation procedure is necessary in order to close the still patent bronchi In consequence it is my practice to carry out an extrafascial mobilisation with the thoracoplasty

More recently modifications of the Monaldi technique have been introduced the most notable being that of Maurer who by dilating the track with specially

constructed laminaria tents inserts a tube of large bore through which streptomycin is introduced and attempts are made to cause cicatrisation of the bronchi with chemical agents

Open Drainage of Cavities

This operation is not commonly practised in this country but is used fairly extensively on the continent. The same principles are involved as in the previous operation but it is claimed that more complete access is had to the cavity walls and that the bronchi can be cauterised under vision

There are no special points about the technique which is carried out in the same manner as that for drainage of an acute lung abscess

III RESECTION OF THE DISEASED AREA

LUNG RESECTION

There is at present, an increasing tendency to submit cases of pulmonary tuberculosis to resection. This is due in the main, to the satisfactory results obtained with lung resection for tumours other inflammatory conditions and with the occasional case of tuberculosis which had been quite unsuspected until histological examination of the excised tissue revealed its true nature

Lung resection has the following theoretical *ad antages*

1 The diseased area is excised and the drain made on the patient s resistance against his disease in controlling a large lesion, is obviated.
2 The period of treatment is shorter in view of the above
3 Cases not satisfactorily amenable to relaxation procedures are satisfactorily dealt with by resection

Only a sufficiently long and careful post-operative follow-up of a large number of cases will give an accurate assessment of the value of resection It is probably wiser to be reluctant to abandon methods which gi e good results with a low mortality and to reserve resections for those cases which do not react favourably to relaxation procedures

INDICATIONS FOR RESECTION

At present it is generally accepted that the following groups of cases should be submitted to resection as a first choice

1 *Tuberculoma* or the closed tuberculous lesion These cases are rarely diagnosed pre-operatively except by exclusion or on suspicion. They are most commonly diagnosed as an endopulmonary tumour or a non-specific inflammatory lesion The results with this type of lesion, however are generally very favourable and it is interesting to note that there has been no evidence of tuberculous bronchitis in the cut end of the bronchus of the lobe removed for this type of lesion (Fig 160)

2 *Tuberculous Broncho-stenosis* especially if there be any secondary infection of the bronchi behind the stenosis In the latter circumstances it is the infecti e element which demands treatment When there is no secondary infection and the stenosis affects the upper lobe which is ca itated thoracoplasty is still the operation of choice When the lower lobe is affected, however with or without concomitant cavitation in the lobe resection offers the best chance of cure because these bronchi

are much more liable to secondary infection. Their secretions tend to be retained more easily than those in the upper lobe which are subject to gravitational drainage during the bulk of the twenty four hours. (See Fig. 161.)

3. *Cavities in the Basic Segments of the Lower Lobe and Certain of Those in the Apical Segment of the Lower Lobe* (Fig. 162). The results of treatment of cavities in the basic segment by any combination of relaxation therapy other than a perfect artificial pneumothorax are disappointing, resulting in only 33 per cent of cavity closures and sputum conversions. The reason for this is that the under-surface of the lobe easily becomes adherent to the diaphragm as a result of the underlying

b

Fig. 160. Mr. H. E. W., aged 52. Patient picked up by mass radiography. Shadow at right apex. Quite asymptomatic.

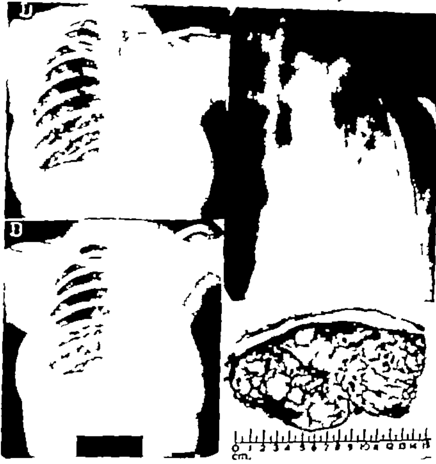
X-ray shows an opacity at right apex, outer margins of which are rather irregular. Bronchoscopy—bronchial tree normal, within telescopic vision. Pre-operative diagnosis uncertain between new growth and tuberculoma. *May 27, 1947*. Right upper lobectomy. On opening the chest, posterolateral segment of upper lobe firmly adherent to chest wall. There was, however, considerable local emphysema around the mass. There was no enlargement of the hilar gland and it was decided that the mass was probably not carcinoma. Probably tuberculous. Upper lobectomy performed. *Examination of the specimen showed it to be localised tuberculous broncho-stenosis with large cavity containing tuberculous pus.* This possibly is blocked cavity despite the lack of any previous history of chest disease. Post-operative course smooth. Seen one year following operation. General condition excellent. No symptoms.

b. X-ray shows both lung fields clear. The patient has gained weight.

disease, making concentric relaxation of the diseased area impossible. Cavities in the dorsal lobe have the following characteristics:

(a) The dorsal segment is relatively small and narrow in its limits and in consequence contained disease early produces adhesions of the lung not only to the parietal pleura in the costo-vertebral gutter but also between the lung and the posterior aspect of the main or descending bronchus to which it is closely applied. These two factors prevent satisfactory relaxation and even when the lung is free in the costo-vertebral area, adhesion to the bronchus still prevents adequate relaxation.

a b



c d

Fig. 61. Mrs. E. S., aged 30. *Jan. 1948.* Admitted to hospital with history of pulmonary tuberculosis since 1943. Contralaterally artificial pneumothorax had been induced at the outset, and been maintained for three years when it obliterated. Continued to have cough and sputum which remained consistently positive despite nine months' bed rest before admission to hospital. At time of admission, left lung collapsed.

a, X-ray shows appearances at this time.

b, Tomograph through area of left main bronchus showing it to be reduced to a fine track and also shows cavitation in the lung parenchyma. *Jan. 22, 1948.* Left pneumonectomy under streptomycin cover. Pneumonectomy carried out in the extrapleural plane until the level of the hilum was reached. Post-operative course smooth except for small rise in temperature. *Feb. 19, 1948.* Left thoracoplasty. Resection of ribs to 8. Pleural space opened. Contents sucked out, but no flap was cut.

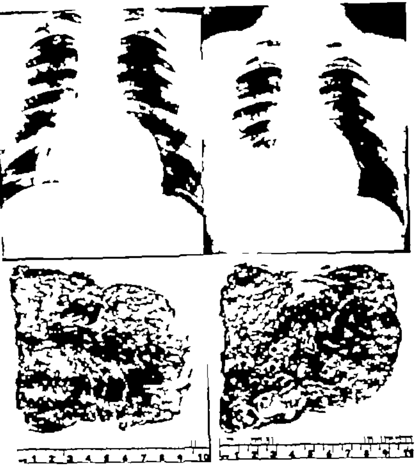
c, X-ray shows condition six months later. To date patient's condition excellent. No cough or sputum.

d, Photograph shows cut surface of lung demonstrating severe bronchiectasis, areas of cavitation, and cavities filled with pus; also the marked thickening of parietal pleura.

(b) The bronchi to the segment are relatively shorter so that bronchi of larger degree are destroyed by the ulcerative process, occasionally to such an extent that the primary subsegmental bronchi or even the main segmental bronchus opens

directly into the cavity These bronchi are much more rigid than those affected in apical lesions and are less affected by smaller degrees of relaxation

b



d

Fig 61 Mr H C aged 23 *October 1947* Routine x-ray showed bilateral pulmonary tuberculosis. Sputum positive *Feb 11 1948* Right phrenic and pneumoperitoneum *Sept 24 1948* Admitted to hospital. Cavity and infiltration in lower lobe Sputum positive Artificial pneumothorax unsuccessful Bronchoscopy—no satisfactory evidence of tuberculous bronchitis.

X-ray shows cavity in lower lobe with infiltration and collapse Nov 1 1948 Right lower lobectomy Uneventful convalescence

b X ray shows condition of patient two months after operation

Photograph shows lobe removed. Cavity in this lower lobe

d Photograph shows section of the lobe about inch peripherally to the cavity showing the degree of bronchiectasis affecting this area It will be noted that there are scattered infiltrations throughout the lobe in both sections.

These two factors singly or most probably in combination offer an explanation for the lower percentage of cavity closures which occur with artificial pneumothorax even when the artificial pneumothorax is perfect than occur with cavities in the upper lobe

These considerations are the basis for the choice of resection in these cases, but it should be stressed that when apical cavitation is present as well thoracoplasty should still be the operation of choice as many of the cases will be satisfactorily controlled by this procedure most certainly the dorsal lobe ca ities, in combina tion with apical disease if the mobilisation of the lung is sufficiently extend e.

4. *Ruptured Cavities into an Artificial Pneumothorax* complicated *as nearly all of* these cases are with an empyema This accident most commonly follows cauterisation of adhesions The cavity distends and bursts, with resulting marked toxaemia, high fever and tachycardia It is a most grave complication carrying with it an exceedingly high mortality when treated by conservative means and warrants a serious intervention especially as the results following resection are very satisfactory

Many American writers advocate resection for all distension cavities even in the absence of the above complication, maintaining that these cavities cannot be closed by thoracoplasty but this latter view is contrary to personal experience

Factors Influencing Choice of the Operation

Before a decision is made to submit the patient to a resection there are certain points which will need consideration apart altogether from the patient s ability to withstand the operation Firstly in all cases when the resection is to be done for cavitation it is essential that all minor forms of relaxation therapy—artificial pneumothorax, diaphragmatic paralysis and pneumoperitoneum—shall have been tried without success Secondly the contralateral lung should be free from disease although there is some evidence that resection can be safely undertaken in the presence of contralateral disease provided it is minimal and is not cavitated Resection can be carried out even when the disease has been ca itated provided it was originally a small lesion and is controlled satisfactorily by an efficient artificial pneumothorax

In all cases the radiographs must be studied carefully to determine the presence or absence of disease in both the contralateral lung and the upper lobe of the affected side and if possible frequent tomographic cuts should be taken of these areas. It *is most disturbing on opening the chest to find quite sizeable* lesions in the upper lobe which ha e not been revealed by the pre-operative studies

Thirdly all cases should be submitted to pre-operative bronchoscopy This observation is almost unnecessary as it should be a canon that no lung resection should be done without previous bronchoscopic examination irrespective of the condition for which it is to be performed.

Bronchoscopy will give evidence of a broncho-stenosis or a tracheo-bronchitis It is worthy of record that the latter may be present without the usual visual evidence associated with it, i e redness, oedema, granulations or ulceration also even when the mucosa itself is normal In all cases with cavitated lesions there is evidence of tuberculosis of the submucosal layer at the level of the bronchial section

Pre-operative Preparation

A large percentage of the cases submitted to operation have already had a dia phragmatic paralysis and pneumoperitoneum instituted. If neither has been done a pneumoperitoneum should be induced a few days before the operation. These procedures decrease the volume of the hemithorax—a valuable consideration

following lobectomy in that the remaining lobe which may contain small unsuspected lesions is not subject to o erdistension After pneumonectomy the residual space which has to be obliterated is rendered smaller

The operation is performed under a cover of parenteral streptomycin A daily dose of 0 5 gm of the drug is given night and morning from about two days before the operation and for about three weeks after operation The warning already given about the indiscriminate use of streptomycin needs reiteration There is ample evidence to show that tubercle bacilli in quite a high percentage of cases will develop a resistance to the drug if the treatment is sufficiently prolonged. Hence it is unwise to exhibit the drug in all cases in the hope that some good may accrue there being two serious objections to such indiscriminate use Firstly it may be that at some future period during active treatment streptomycin may be quite invaluable in the control of a recent spread This is the type of lesion which reacts best in view of the fact that the blood supply to the lesion is much nearer to the normal than in the older more developed one Secondly there is a serious public health risk of developing strains of resistant organisms in a large number of people which would make them dependent on the discovery of a new antibiotic The rate at which resistance is acquired varies but a sound general principle is that streptomycin should be discontinued after four weeks unless it is obvious that success will attend its continued use

Operative Technique

Anaesthesia The operation is done under general anaesthesia Nitrous oxide and oxygen supplemented by pentothal and curare in skilled hands gi es the best results

Position of the Patient A balloon catheter is placed in the bronchus of the lobe to be removed or in the main bronchus if the whole lung is to be taken away in order to minimise the risk of aspiration of secretions into the unaffected area of lung which is to be conserved. Following Overholt many surgeons use the face-down position to avoid spill-over They claim that this position encourages the flow of secretions down the trachea away from the bronchi and also that it makes the bronchus more accessible The position is a matter of choice and depends to a large extent on the facility with which the surgeon himself can operate in the chosen position, personal preference being for the lateral position

Exposure of the Lung The chest is entered through the periosteal bed of the resected 6th rib the latter being removed from just in front of the transverse process almost to the costal cartilage Not infrequently it will be found that the pleura is universally adherent and if so the separation is carried out in the extrapleural plane sufficiently to insert the blades of a suitable rib spreader The spreading of the ribs is done manually and should be carried out in stages the maximum degree of spread being obtained after two or three attempts made at intervals Where there has been no pleural infection and there is a free pleural space the pleura is opened it is safer however to strip the pleura off the chest wall at all points where the lung is adherent so as to a oid opening into tuberculous area.

Pneumonectomy ISOLATION OF THE BRONCHUS When pre-operati ely a pneumonectomy has been decided upon the main bronchus is secured with a clamp as soon as possible The lung is liberated for a distance above and below the level of the

bronchus this generally is done extrapleurally until the outer margin of the aorta is reached and the pleura is then opened It is a fortunate circumstance that, in the region of the hilum, the pleural layers are often free or at most only lightly adherent. By gentle retraction with a swab on curved holders the pleura on the posterior aspect of the bronchus can be visualised and divided with scissors to expose the *vagus nerve with its pulmonary branches These latter are divided and not infre*quently either one of the bronchial arteries itself or its branches will be divided at this time

The upper margin of the bronchus is defined by scissors dissection and its sheath of peribronchial fibrous tissue opened the lower margin of the bronchus being similarly treated The opening of the sheath is very important, as this structure separates the pulmonary artery and the superior pulmonary vein from the bronchus *If the layer between the sheath and the bronchus is satisfactorily entered blunt* dissection with a pair of blunt-nosed curved forceps can be safely carried out without any risk of vascular damage provided the nose of the forceps is kept close to the bronchus. It is often possible and even safer after the commencement of the dissection with forceps has afforded enough room to separate the anterior aspect of the bronchus with the finger

When the bronchus has been freed a suitable non-crushing bronchial clamp is placed in position Before the clamp is closed the anaesthetist deflates the balloon and withdraws the catheter maintaining suction by the catheter the whole time It is quite easy to see and feel the balloon as it passes the clamp which is then promptly closed and aspiration of the bronchus of the opposite side carried out. This manoeuvre reduces the risk of aspiration of secretions to a minimum After the clamp has been closed the lung can be mobilised either extrapleurally or intrapleurally as indicated so as to give all the access necessary for easy and safe ligation of the vessels

LIGATION AND DIVISION OF VESSELS. The pulmonary artery generally is ligated first as theoretically this allows blood to drain back into the circulation by the veins before they are ligated The order of ligation should not be adhered to however *if technical difficulties indicate that ligation and division of the superior* vein first would ease the situation as sometimes happens on the right side Separation of the vessels is facilitated and made safe by deliberately opening the perivascular fibrous sheath, blunt dissection with forceps being more likely to result in perforation of the vessel wall than sharp dissection. The sheath on the artery on the left side is easily opened and separation from the superior pulmonary vein straight forward and the proximal ligature can be placed close to the origin of the ligament of the ductus arteriosus

On the right side the fibrous pericardium extends from the postero-lateral aspect of the superior vena cava outwards in a triangular fold, to the junction of the origin of the upper lobe branch and the descending branch of the artery the latter descending under cover of the superior vein Division of this extension is essential if the separation is to be done safely and if the proximal ligature is to be placed close to the origin of the artery from the parent trunk. Ligation performed without division of the band is carried out at the level of the branches and not on the main right branch itself thus leaving a blind pouch between the ligature and the main pulmonary artery Separation of the circumference of the artery If the

sheath has been entered properly can most often be carried out with the finger without the ri k of perforation of its wall If forceps must be used the greatest care must be taken to avoid this accident In these cases it has not been necessary to undertake intrapericardial ligation of the vessels as not uncommonly happens in cases of carcinoma The proximal ligature is then tied with No 25 linen thread and while this is being done tension on the lung should be relaxed because the ligature may cut through or not be tied sufficiently tightly if tension on the vessel is maintained Thick linen thread is preferable not because of the risk of finer material not holding but to minimise the risk of the ligature cutting through the vessel wall

Distal ligatures are now placed on the branches on the right side and on the left side on the first branch of the artery and beyond it. This lea es a long cuff of the artery beyond the proximal ligature after the artery has been divided and does away with any tendency for the ligature to slip Some surgeons doubly ligate and even transfix this artery but this is quite unnecessary if the above simple precautions are adopted

The veins both superior and inferior are similarly treated and divided

The separation of the lung from the chest wall diaphragm pericardium, and mediastinum is now completed with or without the pleura as indicated. It will incidentally be found difficult to remove the pleura from the central tendon of the diaphragm and from the pericardium, and it is fortunate that in the great majority of cases the lung is only lightly adherent in these areas

DIVISION OF THE BRONCHUS The lung is now attached only by the bronchus A further clamp is placed distal to the one already in position and the bronchus is di ided between the two any secretions caught between the two being sucked away By grasping the proximal clamp one can now free the bronchus from the oesophagus posteriorly and the pericardium anteriorly The inferior tracheo-bronchial and the parabronchial glands in the lateral tracheo-bronchial angle are then excised this should be done cleanly in order to avoid leaving behind fragments of glandular tissue from which infection may arise.

CLOSURE OF THE BRONCHUS After due warning to the anaesthetist the bronchial clamp is removed and the level of the carina can then be isualised. It is only in this way that the clamp can with certainty be placed on the carina It has been found impossible to assess the level of the carina by external evidence even when the medial wall of the opposite bronchus is as is generally the case clearly in iew Too great stress cannot be put on this point because herein lies the secret of successful bronchial closure

A great deal has been written on this question of bronchial closure and many and aried suggestions have been made as to its attainment. It is now however generally agreed that the prime factor of importance is the amputation of the bronchus flush with the level of the bronchus of the territory of lung which is to be left behind Amputation of the bronchus distal to this point lea es a blind pouch above the level of the suture line Secretions collect in this pouch which cannot be removed by coughing and because of their iscosity are not removed by ciliary action. They are generally infected from the outset or tend to become so This infection seeps along the l ne of suture and a peribronchial abscess is formed which is followed either by an empyema or a bronchial fistula, or both.

The clamp is placed in position encroaching slightly on the tracheal lumen and

the redundant portion of the bronchus is amputated about 1 5 to 2 mm beyond the clamp Any exposed portion of bronchial cartilage is removed because it resists infection badly and the bronchial end is closed with a running suture Many types of material have been advised for the suture but the easiest to work with is fine thread which has previously been drawn through sterile soft paraffin This gives uniformly satisfactory results Its only disadvantage being that occasionally the suture sheds itself into the bronchus at a later date and may need to be removed bronchoscopically

After the bronchial suture has been completed a flap of pleura is sutured over the stump this can quite conveniently be a free graft and generally sufficient can be found from the mediastinal margin or over the aorta This latter is possibly not essential but final evidence has been obtained ten days after operation that the graft rapidly becomes a thick vascular membrane which helps to reinforce the suture line

When haemostasis is satisfactory the chest is closed without drainage 1 gm of streptomycin being left in the cavity

Lobectomy The following considerations govern the performance of a lobectomy

Firstly the upper lobe is carefully examined to ascertain whether or not an unsuspected foci is present This may necessitate a change to a pneumonectomy

Secondly unless the fissures are complete or can be made so without cutting into the upper lobe and unless there be some serious reason for not proceeding to total lung resection such as the presence of a contralateral artificial pneumothorax, a pneumonectomy is the preferable procedure

Thirdly the lobar hilum is most often the site of a fairly severe peribronchitis which spreads to include the pulmonary artery and not infrequently there are many enlarged and fibrotic lymph nodes. These findings make isolation of the bronchus as a first step dangerous in that perforation of the posterior juxta bronchial wall of the artery would be likely to occur Hence it is safer to secure the artery as a first step If the lobes are adherent the fissure is opened by sharp dissection preferably with a knife until the superficial aspect of the artery is exposed Generally however the artery is covered by perihilar lymph nodes which must be excised before the artery is exposed. The artery and bronchus in this position are also enclosed in a common fibrous sheath a septum in the sheath separating the two structures This sheath must be opened and often the walls of the artery have to be separated from the sheath by sharp dissection so as to free the posterior aspect. Not infrequently it is of help to free the branch to the dorsal lobe first and doubly ligate it and divide it gentle traction on this branch then gives a lequate access to the posterior aspect of the trunk going to the basic segments Most often the branch to the lingular segment of the upper lobe on the left side comes off immediately opposite the branch to the dorsal part of the lower lobe and occasionally it may come off at a slightly lower level

The bronchial margins are defined inside the sheath and can then be isolated with a pair of blunt nosed forceps and a bronchial clamp placed in position preparatory to remo al of the endobronchial balloon as described earlier

The same meticulous care should be taken in the level at which the clamp is placed relati e to the upper lobe bronchus as in pneumonectomy relative to the carina

a *b*

d

Fig 63 Mrs I Q., aged 27 *Sept 1945* Diagnosed pulmonary tuberculosis.

X ray shows large cavity right side in dorsal lobe with extensive infiltration of lower lobe Right artificial pneumothorax attempted This was abandoned and followed by right phrenic crush and pneumoperitoneum General condition improved Went home *Jan 1947* Cough and sputum recurred. *April 1947* Phrenic recrushed and pneumoperitoneum, which had been abandoned was re-induced. Went to sanatorium. *June 16 1948* Admitted to hospital

b X ray shows pneumoperitoneum with diaphragm up to level of 8th rib posteriorly Lower lobe collapsed (cavity demonstrated by tomography) also cavity right upper lobe Bronchoscopy No macroscopic evidence of pulmonary tuberculosis. Mucosa smooth and pale Right pneumonectomy decided upon. *Jul 23 1948* Right pneumonectomy under streptomycin cover Pneumoperitoneum maintained.

X ray shows high level to which diaphragm had ascended. *Sept 23 1948* Right thoracoplasty Resection of 1st 2nd, 3rd 4th 5th, and 6th ribs including regenerated portions of 5th through which thoracotomy had been performed The intercostal muscles and periosteum of all the resected ribs were divided anteriorly so as to form a flap which was fixed down on the mediastinum. Post-operative course after both these interventions quite smooth.

d X-ray shows condition three months following operation. General condition good No cough or sputum. It is interesting to note that histological examination of cut end of the bronchus showed the bronchial mucosa was completely replaced by tuberculous granulation tissue despite its apparently normal pre-operative appearance.

the redundant portion of the bronchus is amputated about 1.5 to 2 mm beyond the clamp. Any exposed portion of bronchial cartilage is removed, because it resists infection badly, and the bronchial end is closed with a running suture. Many types of material have been advised for the suture but the easiest to work with is fine thread which has previously been drawn through sterile soft paraffin. This gives uniformly satisfactory results, its only disadvantage being that occasionally the suture sheds itself into the bronchus at a later date and may need to be removed bronchoscopically.

After the bronchial suture has been completed, a flap of pleura is sutured over the stump; this can quite conveniently be a free graft and generally sufficient can be found from the mediastinal margin or over the aorta. This latter is possibly not essential, but visual evidence has been obtained ten days after operation that the graft rapidly becomes a thick vascular membrane which helps to reinforce the suture line.

When haemostasis is satisfactory, the chest is closed without drainage, 1 gm. of streptomycin being left in the cavity.

Lobectomy. The following considerations govern the performance of a lobectomy. Firstly, the upper lobe is carefully examined to ascertain whether or not an unsuspected foci is present. This may necessitate a change to a pneumonectomy.

Secondly, unless the fissures are complete or can be made so without cutting into the upper lobe and unless there be some serious reason for not proceeding to total lung resection, such as the presence of a contralateral artificial pneumothorax, a pneumonectomy is the preferable procedure.

Thirdly, the lobar hilum is most often the site of a fairly severe peribronchitis which spreads to include the pulmonary artery, and not infrequently there are many enlarged and fibrotic lymph nodes. These findings make isolation of the bronchus as a first step dangerous in that perforation of the posterior juxta-bronchial wall of the artery would be likely to occur. Hence it is safer to secure the artery as a first step. If the lobes are adherent, the fissure is opened by sharp dissection, preferably with a knife, until the superficial aspect of the artery is exposed. Generally, however, the artery is covered by perihilar lymph nodes which must be excised before the artery is exposed. The artery and bronchus in this position are also enclosed in a common fibrous sheath, a septum in the sheath separating the two structures. This sheath must be opened and often the walls of the artery have to be separated from the sheath by sharp dissection so as to free the posterior aspect. Not infrequently it is of help to free the branch to the dorsal lobe first and doubly ligate it and divide it; gentle traction on this branch then gives adequate access to the posterior aspect of the trunk going to the basic segments. Most often the branch to the lingular segment of the upper lobe on the left side comes off immediately opposite the branch to the dorsal part of the lower lobe, and occasionally it may come off at a slightly lower level.

The bronchial margins are defined inside the sheath and can then be isolated with a pair of blunt-nosed forceps and a bronchial clamp placed in position preparatory to removal of the endobronchial balloon as described earlier.

The same meticulous care should be taken in the level at which the clamp is placed relative to the upper lobe bronchus as in pneumonectomy relative to the carina.

of these vessels are very friable and tear easily especially the artery which is the most commonly damaged

The safest course is to control the bleeding point with the finger while the artery and posterior aspect of the hilum are cleared The necessity for a large incision and a wide thoracotomy that will allow of sufficient room to work when one hand is in the chest will be fully appreciated at this time

When the hilum has been cleared both artery and main bronchus can be held with a bronchial clamp The artery can now be easily isolated proximal to the clamp or if necessary ligated intrapericardially These manoeuvres of course should be carried out in a clear field Should there be any blood loss the transfusion is speeded up so that the loss is quickly replaced The loss is on the intake side as far as the left heart is concerned and consequently there is an immediate decrease in output with a consequent drop in blood pressure which will tend to persist for a long time unless it is rectified quickly A similar technique is used during lobectomy when the lobar branch is damaged

Complications with the Bronchus The bronchial clamp may be placed too high or may not include the bronchus of the whole of the area to be removed For example the clamp may be placed on the main the descending or the upper lobe bronchus instead of the bronchus to the lower lobe this may seem to be impossible but it is quite easily done If this accident is kept in mind it will be immediately noticed that the area of lung thus occluded does not inflate as it did previously with the rhythmic pressure on the anaesthetic bag No harm will be done to the bronchus if the clamp used has been of the light non-crushing type

Occasionally it is found that a gland has ruptured into the bronchus Under these circumstances the line of section of the bronchus must be above the level of the bronchial defect to use the margin of the defect as part of the line of section will lead to failure of healing of the stump and a fistula

Complications

The commonest complications are post-operative spread of the disease empyema and bronchial fistula These can to a great extent be avoided by careful attention to technical detail All these are serious complications perhaps the least serious since the introduction of streptomycin is post-operative spread The other two at the moment most commonly lead to a fatal termination, but not necessarily so Empyema will need drainage and later a thoracoplasty and the fistula if the patient survives will entail an operation for closure of the fistula and the pleural space

The results of lung resection in our hands are given in the accompanying tabulation.

Results of Lung Resection

Lobectomy		(Deaths)
Pneumonectomy		(Deaths)
Closed tuberculous lesions	9	
Cavitated lesions	9	
Stenotic lesions	3	

CHAPTER 10

Mammaplasty

SIR ARCHIBALD MCINDOE

There is little need to justify plastic surgical procedures on the pendulous breast. The field is as genuine as any other in surgery provided that its limitations are recognised and the patients are carefully selected. Few surgical operations are so satisfactorily measured in terms of human happiness. If they can produce normal breasts for the woman handicapped by the sheer weight of massive hypertrophy, particularly if she is unwilling to submit herself to the equally embarrassing deformity of bilateral amputation. The last twenty years have witnessed such a marked advance in the technique of mammaplasty that it is now possible to offer as an alternative normal mammary configuration, unimpaired function and minimal scarring.

Mammary hypertrophy and ptosis probably result from hereditary influences, glandular excesses or deficiencies, repeated pregnancies, obesity, or other factors acting on a poorly fixed structure. A constantly repeated series of physiological changes give little opportunity for recovery of lost tone, for the weak supports of the breasts, which vary greatly in quality between patients, are unable to sustain any prolonged increase in the weight either of the gland or of its fatty investments. The skin, which is the most important fixative structure, must retain its tonal qualities and elasticity if increase in size is not to be followed by permanent stretching and mammary descent. The difference between the ordinary ptotic breast and the huge hypertrophy of gynecomastia is probably determined by these hereditary and mechanical factors and the degree of endocrine control exercised in the critical years of puberty and adolescence.

TYPES OF MAMMARY HYPERTROPHY

1. *Long Flabby Pendulous Breasts with or without Glandular Hypertrophy. Characteristic of the Adolescent Girl of Otherwise Normal Build, More Often Tall and Slim Than Short and Fat* (Fig. 164, *a*). These are of purely hereditary and endocrine origin. The gland itself usually enlarges to form a spherical mass, which gradually elongates the skin

covering to form a pedicle of greater or lesser length carrying the blood supply to the dependent gland substance Pathologically the gland shows a marked excess of

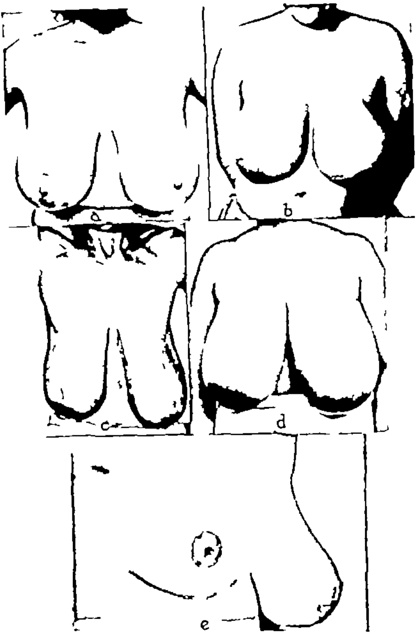


Fig 64 Types of mammary hypertrophy Virginal hypertrophy in girl of 8 *b* Broad heavy breast associated with obesity and pregnancy Sac-like dependent breasts following multiple pregnancy and obesity reduction *d* Gynecomastia. Asymmetry of breasts.

fibrous tissue over the glandular elements and may after some years present chronic inflammatory changes (a condition which Velpeau designated as chronic passive congestion)

2 *Broad Heavy Breasts Which Develop with Obesity and Are Thus Often Associated with Pregnancy* (Fig 164, *b*) This type predominates in women of sturdy squat build and adipose tendency The excessive deposition of fat in and around the gland tissue can produce breasts of massive proportions The skin does not tend to lengthen in the downward direction as it does in the former type

3 *Sac like Dependent Breasts Following Obesity Reduction and Multiple Pregnancies* (Fig 164, *c*) Here after a period of physiological activity or of obesity atrophy of the fat and glandular structures leaves a permanently stretched partially empty skin bag

4. *True Virginal Hypertrophy or Gynecomastia* (Fig 164 *d*) This is uncommon Hypertrophy of the gland itself mainly fibrous with virtual disappearance of the duct system can produce a breast of gigantic proportions sometimes weighing 30 pounds Where the hypertrophy of puberty referred to in Group 1 ends and gynecomastia begins is difficult to say In all probability mild unbalance of oestradiol and progesterol hormones responsible for the former condition over a period of years is suddenly and massively in action in the latter Enlargement can and usually does occur in six months to one year There are many cases however in which this distinction is far from clear

5 *Asymmetry* (Fig 164, *e*) This is probably of congenital origin a defect in the developing breast bud being responsible

Whatever the cause of the condition and the end result of the gland itself whether hypertrophic or atrophic it is clear that mammary descent is due to a disproportion between the weight of the fatty or glandular element of the breast and the strength of the suspensory apparatus Operations on the breast for the relief of hypertrophy or atrophy with ptosis must therefore be based on anatomical considerations of blood supply and skin distribution if the tissues are to be restored to their normal position and normal function whenever this is possible

INDICATIONS FOR OPERATION

Primarily the indications for operation are concerned with the undesirable symptoms produced by the size of the breasts themselves i e. weight, general tiredness backache faulty posture submammary intertrigo cutting straps on the shoulders from supportive apparatus and so forth Many of these breasts are chronically inflamed from passive congestion (Velpeau) or cystic disease and the patient can be observed in the outpatient clinic supporting the breast with her hand while waiting for examination Limitation of social activities is of importance for riding swimming, and dancing become impossible and the patient often exhibits psychic disturbances as a consequence

This is an operation of considerable magnitude. It is done largely for the comfort of the patient so that if it is worth while the risk must be correspondingly small One should be cautious however for some patients who apply for operation are of the type for whom plastic procedures of any kind are inadvisable It is important to discriminate carefully between those who will derive lasting benefit and happiness from operation, and those who will never be satisfied whatever is done The procedure should be fully explained to the patient and the nature of the scars shown to her if possible by means of photographs, so that she fully realises what the end result will be

The patient must be in good physical health prior to operation and should undergo a complete physical examination beforehand Patients in poor general condition with bad skins should be avoided or given an opportunity of putting themselves in the best physical condition Under no circumstances should the operation be done just before or during the menstrual period Bleeding and haematoma formation will almost certainly follow

RISKS OF OPERATION

Despite the magnitude of the operation, there should be no mortality and the dangers are purely those of a general surgical nature and in particular those associated with diminished blood supply When the nipple is transplanted as a free graft it may fail to take, so that the cosmetic result is ruined Where the nipple is transplanted on a breast pedicle partial or complete necrosis may occur—a complication due entirely to bad technique Either the blood supply has been cut down too much or the pedicle rotated too abruptly with interference to the blood supply Necrosis of areas of the covering skin flaps may arise from the same reasons Haematomata may occur but are unusual if haemostasis has been attended to and drainage instituted for forty-eight to seventy two hours Sepsis is uncommon

REQUIREMENTS FOR A SATISFACTORY RESULT FOLLOWING MAMMAPLASTY

In Types 1 and 2 the patients are usually young women in the child bearing period An effort should therefore be made to reduce the breast to a normal size without impairing any function which it may possess prospectively Lactation may be possible and nipple sensation may be regarded as important hence these functions should be preserved In Type 3 while lactation may not be possible the patients are usually most anxious to obtain a result which is attractive cosmetically In fact, that is the ordinary motive for seeking help In these three classes therefore an operation which preserves nipple function is superior to one in which it is destroyed. In Type 4 there is more justification for total removal of breast substance and free grafting of the nipple It has the added advantage of avoiding two-stage procedures Asymmetrical breasts are best treated individually according to local conditions

Whichever method is selected the breasts after operation should be symmetrical with the nipples at the apex and at the same level They should be cone shaped with upper and medial and lateral convexities equal to or slightly less than, the lower The nipples should point outwards and upwards and the areolae should neither be too large nor too close together The scars should be symmetrically placed, carefully made to constitute eventually hair lines while the submammary scars should lie accurately in the submammary grooves and not be allowed to project out into the axilla, where they will be visible in evening dress When resolution of the scars has taken place it should be difficult to tell that an operation has been performed at all These operations should be carried out by plastic surgeons and the general surgeon who would attempt one without previous experience or training should be reminded that the vexation of a woman outraged by an amateurish attempt to construct what she had hoped would resemble a pair of breasts of classic proportions is not easily forgotten

TYPES OF MAMMAPLASTY

Of the considerable variety of methods formerly advocated for reducing the female breast only two have any real place (1) that in which the nipple is transplanted as a free graft and (2) that in which the nipple is transplanted as part of a breast pedicle and attached to its lactiferous tubercles

1 In the first variety no effort is made to preserve the function of the breast. For cosmetic reasons only the nipple is free grafted on to the skin of the chest wall at the appropriate position and sufficient underlying tissue, either fatty or glandular as required, is built up beneath it to give the shaped form of rounded breast This type of operation is easy to perform and is particularly indicated in women at or approaching the menopause where a satisfactory result without risk of skin or tissue necrosis is desirable The breast can be quite satisfactory from a cosmetic point of view but it is an ersatz structure at best, and one which should have little place in a field when function should be the primary object

2 That method of mammaplasty in which the nipple is transplanted as part of a breast pedicle and attached to its own lactiferous tubercles is unquestionably the more desirable. The nipple lies near the apex of a breast tissue pedicle cut in such a way that th peri areolar circulation is not endangered by the removal of the excess The nipple is transplanted to its appropriate position, while the breast tissue is arranged in such a way beneath it that a cone is made which can be clothed in skin with a minimum of scarring In short, a segmental removal of fat and gland substance is carried out, leaving the remainder in a suitable position to function as best it can These functions should be secretory and sensory The cosmetic result is entirely dependent upon the operator s skill sense of form and contour and in the last analysis his artistry as a craftsman

PRE-OPERATIVE PREPARATIONS

On the evening before operation, the entire chest back and front is prepared together with the arms and upper part of the abdomen, ether soap, or spirit being used The whole area is painted with acriflavine 1 1 000 or merthiolate solution 1 1 000 and covered with a sterile jacket. The treatment is again applied on the operating table

THE OPERATION

Position on the Table

It is an advantage to use an operating table which breaks in the centre so that the two ends can be elevated to give a semi-sitting position with the patient s chest at an angle of 45 degrees to the horizontal Thus the breasts fall into their normal dependent position and the measurements for the position of the nipples can be more carefully made With the anaesthetist supporting the head and a nurse pulling forward on each arm the anaesthetised patient is drawn up into a full sitting position and the skin of the entire chest and upper back again sterilised She is then laid squarely back on a sterile sheet placed beneath her care being taken to see that the shoulders are level The arms are then placed akimbo with the hands behind the hips The anterior surface of the chest is towelled off from the sternal notch above to the upper abdomen below and laterally excluding the axillae and arms If this is

done symmetrically the accurate placing of the breasts will not be confused by extraneous irregularities (Fig. 165)

Measurements for Nipple Positions and Marking of Incision Lines

A great number of methods have been described for the accurate placing of the nipples. Some of them are complicated and difficult to apply. While it is true that an appreciation of the classic form is probably helpful in deciding this point, some form of accurate measurement should be made to avoid mistakes in the level of the breasts and the internipple distance, for an error of half an inch becomes painfully apparent at a later date. Unquestionably the patient's general configuration, size and body habitus must be taken into account. Assuming that the levels are correct the commonest mistake is to get the nipples and breasts too close together.

I have found a large compass of great aid in calculating the new nipple position. Using the sternal notch as the centre, a circle is drawn with a radius varying between 6 to 7½ inches depending upon the height and shoulder width of the patient. This

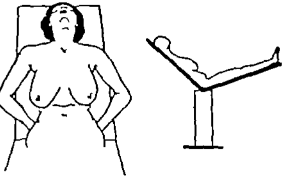


Fig. 165 Operating position: half sitting with arms spread to give access to axillae. Breasts dependent. (Gillies, Sir Harold and McIndoe, Archibald H. In Surgery, Gynecology and Obstetrics, Vol. 61.)

intersection of the two circles gives the approximate position of the nipples. The internipple distance should rarely be less than 9 inches and minor corrections can be made according to the judgment of the surgeon. The new position for the nipple is then marked by stabbing the skin with Bonney's blue. The assistant then stretches the areolae tightly and evenly with two hands and a 1¾ inch circle is drawn round them with a smaller compass, this particular measurement varying in accordance with the wishes of the patient.

If the single upper flap method is to be used, a transverse line with its convexity upward is now marked out from the inner end of submammary groove. If the second method is to be utilised, a vertical line is made from the new nipple position to the top of the areola, and from the bottom of the areola downward to the submammary groove. It is better to mark out on both sides with Bonney's blue all proposed incisions before the skin is actually cut in order that no mistakes may be made in the symmetrical placing of the breasts. These markings, however, must be used rather as an initial than as a final guide, for minor alterations may be necessary when the skin flaps are eventually adjusted to fit the breast tissue (Fig. 166)

Operative Details

1 *Transplantation of the Nipple as a Free Graft* This method of breast reduction, advocated by Thorek and Adams is indicated for extremely large and pendulous breasts of Types 1 and 4, especially where a quick result is desirable or where chronic passive congestion makes removal of all glandular substance imperative But the end result is not as cosmetically attractive as it should be and the resultant structure is functionless It is claimed that free grafted nipples rarely fail to take and that this method therefore has advantages over pedicled grafted nipples where necrosis occasionally occurs Judged by the frequency with which the author has seen necrosis of free grafted nipples this claim cannot be upheld It may best be described as a second choice and as an alternati e to bilateral amputation and should be reserved for those cases where this procedure might otherwise have been considered.

TECHNIQUE The correct position of the new nipple is determined on the chest wall at the root of the breast by the compass method just described. A circle of

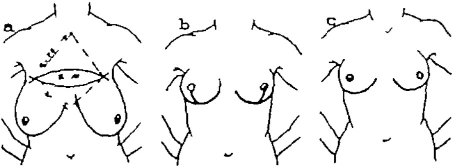


Fig 66 Determination of new nipple position by intersecting circles using the suprasternal and xiphoid notches as centres Radii vary with body habitus but are within limit indicated, b and c Position of scars after operation *b* after double flap operation *c* after single flap operation. In both cases nipples look forward and outward (Gillies, Sir Harold and McIndoe Archibald H., in Surgery Gynecology and Obstetrics, Vol. 68)

$1\frac{3}{4}$ inches diameter is described with Bonney s blue The skin included in the circle is then dissected off to near full thickness leaving a very thin layer of bleeding dermis and taking care not to expose fat too freely The nipples and areolae are then circumscribed with circles of the same diameter and dissected off as full thickness grafts Beneath the nipple itself the dissection goes more deeply to include some smooth muscle The nipples and areolae are then transplanted into their new position with fine interrupted silk sutures and may be quilted down to obtain more adequate immobilisation

The excess skin and breast tissue is removed by semicircular incisions above and below the breasts at the level of the submammary fold with as much reshaping of the remaining mammary substance as is consistent with the life of the transplanted nipples Th incision finally lies in the submammary groove Transplantation of the nipples may be carried out under local anaesthesia as a preliminary operation followed by resection of the breast under local anaesthesia two or three weeks later Both stages may be combined The nipples are immobilised by an elastic pressure dressing for seven to ten days whether the operation i done in one or two stages

2 *Transplantation of the Nipple as Part of a Breast Pedicle* The areolae are circum cised superficially and the skin undermined for a distance of half an inch laterally without damage to the subareolar plexus of veins (Fig 167) The vertical or transverse line is opened and preparations are made for the separation of the breast tissue from its skin covering This is carried out by scissor dissection taking care to leave the plexes of subcutaneous vessels intact (Fig 168) The stripping method formerly described is now abandoned owing to the danger in certain cases of the plane of separation being too close to the dermal layer

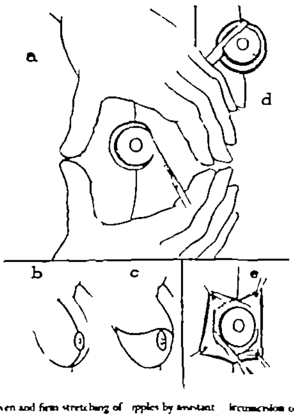


Fig 167 Even and firm stretching of nipples by assistant circumcision of areola. *b* Double upper flap method Single upper flap method. *d* Superficial undercutting of skin surrounding areola, thus avoiding injury to subareolar plexus of vessels. Application of four forceps at indicated points Extension of undermining at deeper level. (Gillies, Sir Harold and McIndoe Archibald, H., in Surgery Gynecology and Obstetrics Vol. 68)

Mobilisation of the skin must be done to a definite plan for upon its nature and extent will largely depend the eventual form of the breast It should be carried upwards downwards medially and laterally so that by the time the breast tissue is entirely free the chest wall has been reached in a circle which will form the base of a cone upon which the breast substance can be built up Excessive or inadequate mobilisation will result in a distortion of the base of the breast cone and in particular different degrees of mobilisation on each side will result in differently shaped breasts

Aufricht has devised a useful sliding circular ruler to determine the amount of

undermining permissible and to equalise it on the two sides. Too extensive a base will result in a flat bun-shaped breast, while the reverse can produce a long narrow organ The common mistake is failure to undermine high on the pectoralis major This should reach as high as the second rib, so that the normal swelling of breast substance may begin at this point

The Formation of the New Breast Cone

This can be done in a variety of ways depending on the amount of breast substance to be removed (if any) and the distance which the nipple must travel to reach its normal position.

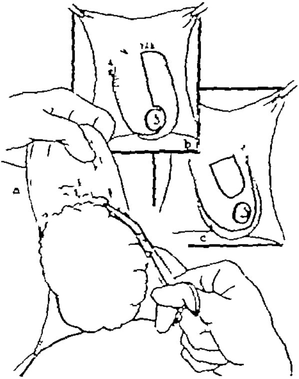


Fig 61 Method of scissor dissection of skin from breast substance *b* Shaped excision of redundant breast substance to form internal pedicle *c* Excision of upper central portion to form double pedicle

In Type 3 it may be unnecessary to remove any breast tissue for after adequate mobilisation only sufficient remains to re-form it into a satisfactory breast cone In others reduction is effected by stripping the investing fatty layer from the surface of the breast or by a simple segmental resection below or laterally The gap so produced is closed with a few light catgut sutures In all the larger more pendulous forms however an extensive reduction and transposition is required. Here a breast pedicle is designed to enable the nipple to survive and at the same time give it sufficient mobility to reach its new site

There are three possible types of breast pedicle

(a) An external pedicle based on the branches of the lateral thoracic artery the medial half of the breast being cut away *This method has been abandoned*

(b) Resection of the upper and middle portion of the breast to form a U shaped pedicle so preserving the lateral thoracic and perforating internal mammary arterial supply and carrying the nipple at the apex of the U

(c) Resection of the lateral half of the breast with free mobilisation of the medial portion particularly along the lower border of the pectoralis major preserving the perforating branches of the internal mammary artery to form a freely vascular internal pedicle with the nipple and areola near the most dependent position This is the preferred method in most instances

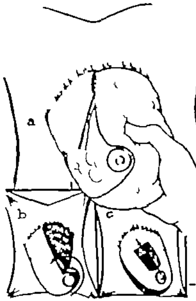


Fig 69

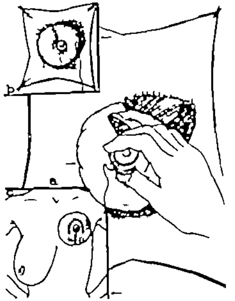


Fig 170.

Fig 69 Formation of internal pedicle of left breast Deep incision t expose pectoral fascia. Hand holds part to be removed. *b* Internal pedicle complete Rotation indicated. Formation of double pedicle following removal of upper central portion of breast tissue (Gillies, S r Harold and McIndoe Archibald, H In Surgery Gynecology and Obstetrics, Vol. 68)

Fig 7 Rotation of pedicle and correct placing of nipple, *b*, Fixation of breast cone to pectoral fascia Infolding sutures inserted t bring ipple forward. Method of suture for double pedicle (Gillies, Sir Harold and McIndoe, Archibald H In Surgery Gynecology and Obstetrics, Vol 68)

The Formation of the Breast Pedicle

The internal breast pedicle designed by Biesenberger is made by an S-shaped incision which begins along the lower border of the second rib sweeps vertically at the level of the inner border of the areola, turns laterally to skirt the nipple and i carried off medially to the end of the pendulous breast The double pedicle is made by the removal of a V-shaped portion of the upper middle segment of the breast followed by complete mobilisation of the inner and outer pedicles which are reduced in size to form a U-shaped tube of breast tissue carrying the nipple at the apex of the U In the case of the single internal pedicle it is rotated upon itself laterally until the nipple corresponds to the position as marked on the skin the tail being secured to the pectoral fascia at the level of the second rib By judicious

placing of plain catgut sutures It is then built up into a cone pointing forward and outward with the nipple on its apex The cone should not be dragged or pulled in such a way that interference with the blood supply occurs. In the case of double pedicles these are folded in W form to produce the desired contour of the breast. In both cases the base of the cone is fixed to the pectoral fascia and muscle by a series of interrupted catgut sutures (Figs 169 and 170).

Reduction of the Covering Skin

This may be effected by (a) a single upper flap through which the nipple is transposed thus giving a single transverse scar in the submammary line As it is impossible with this method to pinch in the submammary skin or to construct an efficient skin support for the underlying cone of breast tissue, it is no longer used The resultant breast is always too broad and heavy below (b) Double lateral flaps below the nipple level with excision of a suitable amount of skin between it and the transverse submammary groove The second method is nowadays most often used because a better breast form can be achieved by it with a shorter submammary scar and the operation can be more frequently performed in one stage than with the single upper flap design.

Treatment of the Skin Flaps

The upper skin flap is brought down over the breast cone and sufficient of the submammary skin is excised to allow easy approximation of the edges to form a single transverse submammary scar As a rule the upper flap is larger than the lower and should be fanned in with interrupted sutures to make it as short as possible A fine hook is then inserted into the marked position of the new nipple on the upper flap a cone of skin is lifted and cut off with sharp scissors This will gi e a perf-ct circle and the nipple itself will be found lying beneath It is then extruded and sutured to the skin edge with finest silk.

In the formation of lateral flaps the breast cone is firmly clothed with skin and the entire excess is drawn together and downwards beneath the breast where it is grasped by Allis forceps from the marked portion of the nipple to the submammary groove An equally satisfactory method is to use large curved gastro-enterostomy forceps which can more faithfully reproduce the curve of the breast The forceps are adjusted in such a way that the skin fits neatly and firmly over the cone of breast tissue and in particular that the sling of skin beneath the breast really supports it efficiently Any slack is taken up in the grip of the forceps.

At this point the inaccuracy of pre-operati e measurements becomes apparent for they rarely coincide with the eventual lines of skin section after all adjustments have been made The skin tension can be and in fact must be considerable but it is not so great as to interfere with the blood supply of the flaps. The excess skin is then cut away and the sutures completed The length of this suture line should be equal to the upper medial and lateral distances from apex to base of the reconstructed and skin-clothed breast cone a point checked by actual measurement holding the lower end of the suture line against the chest wall so as to squeeze the breast cone firmly into its new skin co ering With the large compass the exact position of the apex of the skin cone is checked A circle is drawn corresponding to the

subjacent nipple incised and through the hole the nipple is extruded and sutured into position with fine silk (Figs 171 and 172)

The submammary excess of skin can then be dealt with in one of two ways either vertically or transversely Vertically the submammary pinching in reaches a maximum at the chest wall where a deep suture fixes this point to the intercostal muscles Further excision occurs on a vertical plane downward and rather outwards reversing the excision on the breast This method is only possible in slim women with narrow pendulous breasts Transverse excision removes the excess of

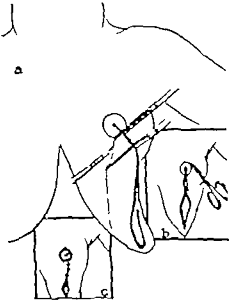


Fig 7

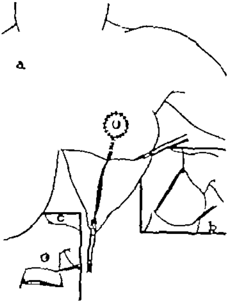


Fig 72

Fig 7 Double upper flap method Skin flaps held with forceps fitted around cone of breast tissue Marking of excision line *b* Removal of excess skin to form double upper flap Inversion of upper and lower sutures Cutting off apex of cone t expose nipple Suture of nipple and vertical scar (G llies Sir Harold and McIndoe, Archibald H in Surgery Gynecology and Obstetrics Vol 68)

Fig 72 Dependent excess of skin drawn downward and marked for excision. *b* Excess turned upward and completion of marking in submammary groove The same process is carried out in the single upper flap method (G llies, Sir Harold and McIndoe Archibald H. in Surgery Gynecology and Obstetrics, Vol 68)

brea t skin in the submammary groove and in addition a good deal of the excess abdominal skin commonly known as the spare tire

In order to preserve good permanent breast form it is desirable to fix the transverse incision close against the chest wall so that the breast substance cannot slide behind it to produce the hollow sagging breast with upturned nipples so commonly seen after reconstructi e operations This is done by means of 3 or 4 deep silk sutures attaching the skin edges to the chest wall The sutures are left in for fourteen days to ensure a sound fibrous tissue attachment The rest of the submammary suture is with fine interrupted silk sutures If there is any excess of skin at the ends of the transverse incision these are treated by the usual triangular excision A tube

is inserted at each end of the incision Firm supportive crepe bandage pressure is maintained for seventy two hours without disturbance (Fig 173)

POST-OPERATIVE CARE

It must *not be forgotten that some of the factors which produce shock are present,* namely loss of body heat, extensive tissue exposure and loss of body fluid In this clinic, the patient is *transferred from the operating table into a warm bed brought* into the theatre at the end of the operation No further lifting or disturbance is necessary *for some hours Post-operative rectal fluid is always given as a routine* and consists of hot tap water given by the drip method Sedative drugs are used as indicated As soon as *the patient is fully conscious she may be raised from the* supine to a sitting position

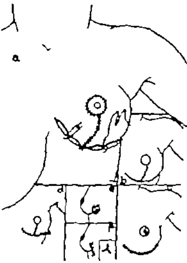


Fig 173 *Closure of submammary incision with interrupted fine silk sutures. b,* Suture completed, double upper flap method. Suture completed single upper flap method. Upper flap is fanned into shorter lower one *d* *f* Method of dealing with excess skin t ends of incision without increasing total length of scar (Gillies, Sir Harold and McIndoe Archibald, H., in Surgery Gynecology and Obstetrics, Vol. 68)

The first dressing should be done at the end of seventy two hours, when if indicated, the tubes may be remo ed Routine *cleansing of the whole area with* saline and subsequent drying with spirit is all that is required Stitches must be removed in a good *light with toothless forceps and fine sharp-pointed scissors.* The alternate sutures round the nipple may be removed on the fourth day and on the fifth day the *remainder may come out together with a few from the main scars* All the stitches from the latter should be out by the tenth day the last being those *bearing tension at the corners of the flaps and* those holding the transverse scar to the chest wall Subcuticular stitches will also come out easily by this time but *must be left longer if they will not slip out painlessly* After final removal of stitches, application of a little sterile paraffin will soften and cleanse the scars

As regards con alescence many of these patients tend to overtax their strength too soon after operation. They feel their friends expect them to resume their social

activities as soon as they leave the hospital on the fourteenth day and consequently they are apt to suffer from a marked nervous reaction to what must of necessity have been a profound physiological and psychological disturbance This can easily be avoided by a short period of convalescence in the country or preferably at the seaside Thi gives an opportunity for nerve recovery and stimulates healing, softening of the skin flaps and absorption of bruising Arm exercises may be commenced during this time but vigorous movements should not take place until at least four to six weeks have elapsed following the operation

POSSIBLE COMPLICATIONS

Possible complications which may follow operation are (1) haemorrhage (2) sepsis, and (3) partial necrosis of skin flaps or pedicles

Haemorrhage of slight reactionary type is coincident with recovery from the anaesthetic but if the tubes have been inserted as described, will give rise to no disturbance Secondary haemorrhage is uncommon and may produce external bleeding or more possibly a concealed haematoma which is revealed in time by severe bruising loss of contour and interference with circulation. The treatment is to evacuate the haematoma with all aseptic precautions as there is a liability to infection

Sepsis may be evidenced by a mild stitch abscess or by more widespread infection, and penicillin should be used immediately Variation of treatment is the keynote of success with local infection. The removal of the infected stitch may be followed by dressings with eusol hypertonic saline or glycerine and magnesium sulphate paste The aim is to establish mild antisepsis without damage to tissues If the patient is strong enough, immersion in a warm saline bath is satisfactory so long as the whole breast area is carefully dried with spirit subsequently Infection of a haematoma requires thorough opening and drainage as soon as the diagnosis is made sinus forceps being passed through one of the incision lines into the collection and followed by a tube which is left in situ until drainage ceases

Partial Necrosis of Skin Flaps or Pedicles Loss of covering skin may take place at the apices of the flaps where they meet in the midline beneath the breast. It should rarely occur but if it does so is due to excessive tension or to rough handling of the flaps both gross technical errors A mild necrosis may safely be left to heal of its own accord but anything more than 2 inches should be excised and free grafted without delay Partial necrosis of the breast pedicle may take place at the point where the nipple is attached and may involve the nipple wholly or in part It will be necessary to wait until separation is complete removing necrotic tissue as indicated and many weeks may elapse before healing is complete This is a major disaster for the cosmetic result will be spoiled As with skin necrosis technical errors are responsible

POSSIBLE SECOND-STAGE OPERATION

Three to four months after the first operation, the condition is reviewed and careful note made of any irregularities of contour or scars The latter can be excised and sufficient skin lifted to enable redundant areas of breast tissue to be removed At the same time the transverse submammary scars can be placed accu-

PART III

Abdomen and Pelvis

Subjects who have the physical and mental make-up known as the duodenal ulcer diathesis are now known to secrete excessive amounts of unusually acid gastric juice during the night and between meals Furthermore this secretion is believed to be mainly neurogenic Wolf and Wolff (1944) have shown how dependent resting secretion can be upon the mental state of the subject and the association between worry and duodenal ulcer is well recognised

The purpose of vagotomy is to interrupt the pathway for neurogenic secretion and the route by which mental stress initiates hypersecretion and ulcer relapse Wolf and Andrus (1947) have observed the loss of gastric secretory and vasomotor response to emotional strain after vagal resection The extent of the alteration in resting secretion is summarised in the section on physiological results There is also an apparently permanent reduction after vagotomy in the acid response to histamine and to caffeine (Varrant, 1947)

Also typical of duodenal ulcer patients is their excessively rapid gastric emptying Several investigators from Ketcher who worked with Pavlov to Teorell (1947), have shown that acid ions which remain in the stomach are slowly eliminated, probably by a variety of mechanisms. In patients with the duodenal ulcer diathesis, acid is hurried on into the duodenum before these mechanisms have had time to act. The gastric delay which results from vagotomy is therefore probably another beneficial factor prolonging the buffering action of food and other buffer agents.

INDICATIONS FOR VAGAL RESECTION

Vagal resection is indicated, either alone or as a part of the operation, in a patient with *duodenal ulcer* verified at laparotomy who has been found on investigation to have hypersecretion of gastric hydrochloric acid. Night pain when present is an indication that resting acid secretion is excessive

If there is no evidence of hypersecretion either in the spontaneous resting juice or in response to stimulation by histamine or insulin vagotomy should not be employed or at least not alone for it is in such a patient that a gastric ulcer may develop later in spite of this operation

On no account should vagotomy be resorted to for so-called functional dyspepsia when no evidence of ulcer can be found on exploration

Vagal resection is the operation of choice for *gastro-jejunal ulcer after Polya partial gastrectomy* but in recurrent ulcer following a Billroth I type of partial gastrectomy the ulcer and part of the stomach should be resected and a Polya type of anastomosis be established as well

For *anastomotic ulcer after gastro-jejunostomy* the investigations of secretion are again important, for if there is a raised histamine response a Polya gastric resection should preferably be carried out as well as a vagotomy It is however justifiable to undertake no more than vagal resection if the patient is a poor risk

In *combined duodenal and gastric ulcers* vagotomy is permissible only if the patient's stomach is of the hypermotile hypersecreting type otherwise gastric resection is the treatment of choice and there is no need to divide the vagi as well

Vagal resection is not a suitable treatment for *gastric ulcer* No convincing reports have yet appeared claiming satisfactory results though Harper and Dragstedt (1947) have advocated its use in certain cases Furthermore the results of gastrectomy are altogether satisfactory in this condition The disadvantage which weighs against

gastrectomy for duodenal ulcer namely that it must be radical to avoid recurrence does not apply in gastric ulcer where a more conservative and therefore less dangerous resection is perfectly adequate An additional reason for treating gastric ulcer by gastrectomy is the occasional close mimicry of a benign chronic ulcer by malignant disease

The main advantages of vagotomy over high gastric resection for duodenal ulcer are that it is safer it lessens hospitalisation and it shortens convalescence Nevertheless it should not for preference be used alone if the ulcer is a large one or deeply penetrating nor if there is even slight pyloric stenosis Furthermore vagotomy should not be employed alone in any but a young patient if there has been a history of bleeding In all these cases the ulcer should be resected or at least altogether protected from gastric juice since vagotomy seldom causes absolute achlorhydria

The best operation to combine with vagotomy is a Polya gastric resection and it would seem justifiable to employ a less radical one than has been found necessary when used alone for duodenal ulcer

SPECIAL INVESTIGATIONS AND THEIR INTERPRETATION

Spontaneous Resting Secretion

The most relevant investigation is that of the spontaneous resting secretion. The patient is given a standard meal not less than three hours before bedtime and nothing further is allowed by mouth. A Levin or Ryle tube is passed on going to bed and left in the stomach for twelve hours Continuous aspiration is maintained and the juice is sucked through a 10-c.c bottle into a 2 litre one The 10-c c bottle is detached every hour and emptied into a test tube

In the morning the 12-hourly samples are titrated and charted in the ordinary way The volume of the whole of the night secretion is measured and the pH of the bulked secretion is estimated electrically From these figures can be calculated the total in grams of free hydrochloric acid secreted in the twel e night hours More than 0 5 gm may be regarded as hypersecretion. However a figure less than this may easily result from intermittent blockage of the tube and the acid levels in the hourly samples may be more significant.

Histamine Test

The result of a histamine test may demonstrate that there is hypersecretion to hormonal stimulation, but a low histamine response is occasionally accompanied by high acid levels in the samples of spontaneous secretion. It is the resting hyper secretion which indicates the need for vagotomy A high histamine response without resting hypersecretion, especially in a patient who does not complain of night pain shows that the resting secretion may be in this case relatively less important, and suggests that vagotomy should not be relied upon alone to cure the ulcer In such a case resection of the gastric antrum to remove a substantial part of the source of the hormone gastrin should be considered in combination with vagotomy

Insulin Test

The insulin test is also a satisfactory method of detecting an overactive secretory apparatus and the response has been found to be substantially raised *in* most patients

with duodenal ulcer (Ihre 1938) It does not, however give any information about spontaneous vagal activity which is better measured by investigation of night secretion.

According to Hollander (1946) it is necessary to produce a hypoglycaemia of 50 mg or less per 100 c.c. in order to stimulate gastric acid secretion via the vagus and he now recommends a dose of 20 units of insulin intravenously

Insulin is given to the fasting patient first thing in the morning, and this may conveniently follow the all-night resting secretion test. The stomach is emptied by syringe every twenty minutes for eighty minutes after the injection and the samples are titrated and plotted. The response to insulin ordinarily reaches a higher level than that to histamine

X ray Examination

The radiologist should be asked to report upon the gastric emptying time and the state and function of the pylorus as well as upon the presence of an ulcer The size and shape of the stomach should also be noted, for vagal resection is not a suitable operation to use alone on patients with long, flaccid stomachs being more indicated where the stomach is high hypertonic, and rapidly emptying The least hint of pyloric stenosis should suggest that more than vagotomy is necessary

ANATOMY OF THE VAGUS NERVES

The vagus nerves contain both efferent and afferent fibres The former arise mainly in the nucleus ambiguus of the hind-brain, and the latter have their cell stations in the jugular ganglion and ganglion nodosum whence fibres communicate with the dorsal nucleus in the floor of the rhomboid fossa

The vagi receive communications from other cranial nerves and from the sympathetic trunk, but probably only the latter accompany them to the abdomen.

Behind the lung roots the vagi break up on each side into a plexus. From that, on the right, two or three branches emerge which, together with a branch from the left vagus, form the posterior part of a new plexus on the oesophagus The left vagus is usually represented by two branches which after receiving a twig from the right form the anterior part of the oesophageal plexus. Further small contributions come from the sympathetic trunks.

The vagus nerves enter the abdomen behind and in front of the oesophagus by passing through the oesophageal hiatus of the diaphragm at the level of the tenth thoracic vertebra Just above or actually within the hiatus the vagi are re-assembled into two to four trunks two main nerves being found in over 90 per cent of cases (Walters *et al* 1947) Almost at once however these trunks re-divide

The anterior (Fig 175 a) which is the smaller of the abdominal vagi breaks up into two groups of nerves The left group supplies the cardia, the anterior surface of the fundus and the proximal part of the stomach The right group has three subdivisions one to the body of the stomach not quite reaching the angulus one which runs parallel with the lesser curve to the antrum, but not the pylorus and a third, often duplicated, which enters the lesser omentum and passes to the porta hepatis Here it gives branches to the liver and then descends to supply the pylorus duodenum and pancreas

The posterior abdominal vagus (Fig. 175 *b*) which is larger than the anterior divides into two, sending a smaller part to supply the posterior wall of the stomach and a larger part to the coeliac ganglion.

Relations

The anterior vagus as it lies on the front of the oesophagus is close to the oesophageal branch of the left gastric artery. The left phrenic artery ascends to the left of the oesophagus and the left phrenic vein crosses just above the oesophageal hiatus to enter the inferior vena cava. Another phrenic vein often descends on the left side of the oesophagus to find its way into the left suprarenal vein.

The posterior vagus lies further away from the oesophagus than the anterior and is between the layers of the oesophageal mesentery. Just above the hiatus it lies almost directly on the aorta, but lower it is separated from it by fibres of the diaphragmatic crura as they decussate to form a bed for the oesophagus at the level of the hiatus.

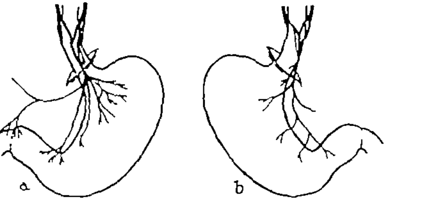


Fig. 175. The anatomy of (*a*) the anterior and (*b*) the posterior abdominal vagus nerves. (After McCrea.)

THE OPERATION OF VAGAL RESECTION

INTRODUCTION

In order that complete vagus interruption might be achieved, Dragstedt (1945) introduced and advocated a thoracic approach, and a number of surgeons followed him in this. In England, however, this method did not find favour except in unusual and special circumstances, and an abdominal technique has usually been preferred (Orr and Johnson, 1947).

The abdominal approach has considerable advantages, *the chief of which is the* opportunity it gives for exploration of the viscera for other lesions, as well as confirmation and thorough examination of the ulcer. Furthermore, such examination will often reveal the need for other procedures in addition to or *instead of* vagotomy—procedures which can only be undertaken through the abdomen.

Perhaps the only clear indication now for transthoracic section of the vagi is unquestionable recurrence of ulceration after the Polya type gastrectomy when there is reason to believe that *the peritoneal cavity has been largely obliterated by* adhesions.

THE ABDOMINAL OPERATION

Preparation of the Patient

The patient is prepared as for a gastrectomy since laparotomy may reveal indications for this or some similar operation The haemoglobin is estimated, the patient's blood group determined and preparation made for transfusion should this prove necessary If there has been vomiting or other reason to suspect water or electrolyte deficiency the blood volume is estimated and the chloride and urea levels are measured

The skin preparation is carried well up over the chest, as a high incision is required.

An hour before operation a twin lumen, double-ended tube is passed, the stomach aspirated, and the tube left in place

Special Instruments

Certain special instruments are essential to ease and success in vagal resection and of these the most important is one providing satisfactory illumination under the dome of the diaphragm A specially designed lighted retractor may be found useful for this purpose

Also needed are long-handled curved Mayo scissors a number of long curved, light weight haemostats, a length of soft rubber tube $\frac{1}{4}$ to $\frac{1}{2}$ inch in diameter and a light blunt dissector with small blades angled on the shaft A combined curved clamp and dissector has been found convenient and economical of time

Anaesthetic

The choice of anaesthetic depends more upon the physical condition of the patient than upon any special requirements of the operation, but as a low lying diaphragm greatly helps the surgeon it is important that the anaesthesia should not be too deep Cyclopropane and curare have been found useful but liable to be accompanied by much oozing from small blood vessels which is a disadvantage when working at such depth. Spinal anaesthesia supplemented by gas and oxygen has also proved very satisfactory and has provided a drier field with minimal relaxation and elevation of the diaphragm The fractional spinal anaesthetic method is especially recommended

Position of the Patient

Diathermy should be available and there should be a kidney bridge beneath the patient's lower ribs If the anaesthetist requires access to a vein the left arm is chosen to rest on an arm board so that the right may lie close to the patient and leave room for a second assistant on the surgeon's left The arms are not folded across the patient's chest

A foot block is fastened to the end of the table and the patient's knees are controlled by a strap or flannel bandage passed round the table so that if necessary the table may be tilted feet down The surgeon stands on the right side of the patient

Technique of Per hiatal Vagal Resection

Incision A midline or left paramedian incision is used and is carried right up to the angle between the xiphisternum and the left costal cartilage On no account

must the incision in the posterior rectus sheath be taken higher than this for the points of scissors can slip too readily between the sternal and costal origins of the diaphragm, wounding the pleura At the lower end the incision reaches nearly to the umbilicus If later it is decided to remove the ulcer and part of the stomach, the incision may cross the midline and be extended down to the right of the umbilicus

Laparotomy After the skin towels have been fixed in position the peritoneum is opened to the left of the midline clear of the ligamentum teres. A thorough laparotomy is then carried out, with special attention to the colon appendix and gall bladder The stomach and duodenum are examined the presence of an ulcer is confirmed and a detailed description made of its position size degree of penetration, adhesion and relation to large blood vessels and of any scarring or stenosis of the pylorus which it has produced

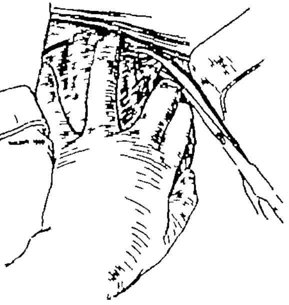


Fig 76 Division of the left triangular ligament of the liver

If no ulcer is detected the lesser omental sac is opened and the back of the stomach and duodenum inspected If still no ulcer is found a second search is made for alternative disease before closing the abdomen

Mobilisation of Left Lobe of Liver If the indications for vagal resection are present, the next step is mobilisation of the left lobe of the liver The left hand is passed over its upper surface and the triangular ligament is allowed to slip between the second and third fingers The liver is drawn down and the assistant places the lighted retractor in the left side of the wound directing the light upwards The left suspensory ligament is then divided close to the liver with curved Mayo scissors (Fig 176) The ligament is not cut blindly because close to its diaphragmatic root there lies a large vein which can give rise to troublesome haemorrhage As the incision approaches the midline the two layers of the triangular ligament are seen to part and are best divided separately in order to avoid wounding the inferior vena cava The caudate lobe of the liver is recognised at this point.

The left lobe of the liver is turned under the right lobe and a sheet of boiled rubber placed over it to serve as a pack, with its rough surface towards the liver and its edge well up to the diaphragm. The second assistant, on the surgeon's left, then takes control of the liver with the lighted retractor The cardia and oesophageal

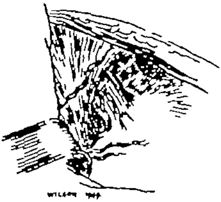


Fig 177 The line of incision in the peritoneum overlying the cardia. Note the phrenic and oesophageal veins, injury to which should be avoided.

hiatus are now well seen If not however the stomach may require deflation through the indwelling tube If necessary the left hand is passed over the fundus of the stomach to draw it down and expose the lower end of the oesophagus and the table may be tilted

Fig 178 Mobilisation of the oesophagus displaying the anterior abdominal vagus.

Mobilisation of the Oesophagus The peritoneum overlying the oesophageal hiatus in the diaphragm is inspected and the position of the several large veins which lie under it is carefully noted

The peritoneum is then picked up and incised (Fig 177) preferably below these veins Usually two well-defined layers are seen and opened The right index finger

is introduced through the incision and passed up into the hiatus alongside the oesophagus where it is swept round completely to free it (Fig 178)

At the back of the oesophagus a stout mesentery is encountered and between the two layers of this the posterior vagus runs Sometimes in thinner subjects the finger tip can be made to present on the medial side of the oesophagus with the oesophageal mesentery stretched over it In this case an ideal opportunity arises to see and feel the posterior vagal trunk between the layers of this mesentery before it is torn through The finger must be worked carefully through the mesentery keeping close to the oesophagus and so stripping off the posterior vagus When the finger has been worked right round the oesophagus the end of a length of rubber tube is placed between the two index fingers It may then be passed round the oesophagus and serves as a convenient retractor by which the oesophagus may be displaced in either direction.

Identification of the Anterior Vagus With the oesophagus drawn well down by traction on the tube, its surface is searched for trunks and fibres of the anterior

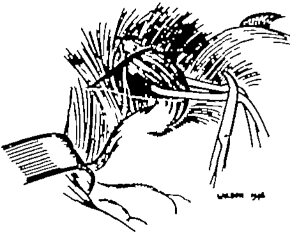


Fig 179 Showing how both anterior and posterior vagi may become displaced to the medial side of the oesophagus with incautious mobilisation.

vagus When the oesophagus is put on the stretch the nerve trunks may invaginate its wall and so disappear from view Partly for this reason they are easier to feel than to see

The anterior vagus is often a single trunk for only a short distance before it enters the abdomen, and if the oesophagus has been inadequately mobilised only the many small branches into which it divides may be found In this case the main trunk may sometimes be recognised at a higher level by passing the finger through the hiatus and palpating the front of the oesophagus.

Sometimes the anterior vagus splits into two trunks one of which is seen passing across to the right side The other may then be found towards the left margin of the oesophagus breaking up into branches nearer to the greater curve of the stomach than is usual

Sometimes the mobilisation of the oesophagus causes the anterior trunk to become displaced over to the medial side (Fig 179) where it may be hidden under the edge of the opening which has been made in the peritoneum Hooked from this

position it may be mistaken for the posterior trunk unless its relation to the oesophagus higher up is investigated.

Resection of the Anterior Vagus When the main trunk has been identified it is picked up with a dissector and seized with a long light haemostat A second haemostat is then placed below the first and the nerve divided between the two Provided that the oesophagus has been well mobilised so that the nerves are exposed at the level where they are resolved into the least number of trunks nothing is gained by drawing the nerves down still further in order to divide them as high as possible In fact, it is much better to avoid damage to the nerve supply to the cardia and lower end of the oesophagus As small vessels usually accompany the nerve its proximal end is ligated with fine silk and allowed to retract into the mediastinum It is probably wiser not to apply diathermy The distal part of the nerve is then dissected well down on to the stomach and diathermised both to control haemor

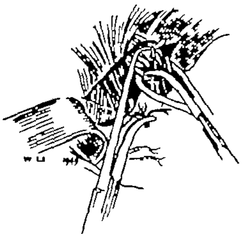


Fig 8 The anterior vagus after di ssion. The nerve has been isolated at high level, so that all branches may be recognised with certainty The actual section has been made at the level of the cardia in order that the branches to the cardia itself might be preserved.

rhage from accompanying vessels and to coagulate the axon sheaths into which regenerating fibres from above might otherwise conceivably grow

It is not necessary to resect a length of nerve Instead, the mobilised piece is turned downwards making the distance between the cut ends even greater than if a length of nerve was removed (Fig 180)

A thorough search is now made for additional trunks or fibres on the front and sides of the oesophagus any found being similarly treated.

Identification and Resection of the Posterior Vagus Before exposure of the posterior trunk is begun the field i dried and any bleeding points are picked up and diathermised The diathermy should not be used directly on the oesophageal wall as it is thin and ulnerable

The rubber tube encircling the oesophagus is now clamped quite close to it with Moynihan gall-bladder forceps and the nose of these is passed up and to the left under the diaphragm to lift the oesophagus out of its bed.

The posterior agus trunk is now sought lying in the oesophageal bed usually

near its right hand margin As a rule it is considerably larger than the anterior trunk often round rather than strap-like and less tensely stretched than the anterior trunk When first recognised it may still be covered by a fascial layer which gives it a pinkish appearance *Sometimes it is concealed by the muscular right margin of the* oesophageal hiatus If it cannot be seen it is felt for particularly just under this piece of diaphragmatic crus a position from which it is easily hooked on the finger (Fig 181)

If the posterior trunk is still not found the oesophagus must be rolled over and its back inspected and palpated as the nerve is sometimes picked up during mobilisation of the oesophagus.

The posterior vagus gives a large branch to the coeliac ganglion, and it is possible to mistake this for the main trunk Even if the posterior trunk appears to have been identified the back of the oesophagus must still be searched for further branches

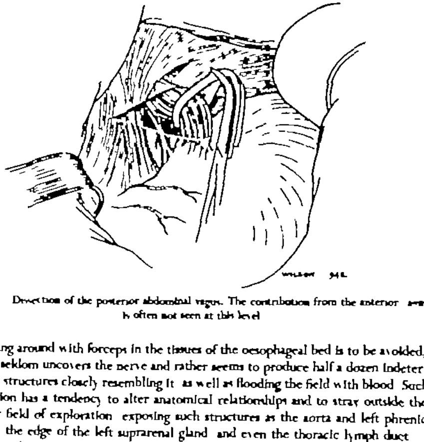


Fig 181 Dissection of the posterior abdominal vagus. The contribution from the anterior vagus is often not seen at this level

Poking around with forceps in the tissues of the oesophageal bed is to be avoided, as this seldom uncovers the nerve and rather seems to produce half a dozen indeterminate structures closely resembling it as well as flooding the field with blood Such dissection has a tendency to alter anatomical relationships and to stray outside the proper field of exploration exposing such structures as the aorta and left phrenic artery the edge of the left suprarenal gland and even the thoracic lymph duct

When the posterior trunk has been identified it is dealt with in the same way as the anterior

Suture of the Peritoneum When the surgeon has finally satisfied himself that all vagal fibres have been found and divided the rubber tube is withdrawn from around the oesophagus and cut edges of the peritoneum over the hiatus are approximated with two or three interrupted sutures Repair of the left suspensory ligament of the liver is not attempted

Introduction of Feeding Tube Before the abdomen is closed, one end of the special two-lumen tube is threaded well down into the small bowel for the purpose of feeding, the suction half remaining in the stomach

Modifications

Moore (1947) has recommended that after section of the vagi the cut ends of the nerves should be enclosed in silk sheaths, turned upwards and sewn into a position well away from the distal ends to discourage regeneration Weeks (1946) and Moore (1947) have both advocated injection of the nerves with procaine before section in order to block hypothetical afferent stimuli at the moment of division which it has been suggested might cause reflex cardiac phenomena

The need for these procedures has not been generally admitted.

Added Operations

Healing of a duodenal ulcer is accompanied by the formation of scar tissue which may constrict the pylorus Though obstruction usually takes many years to become apparent its development may be accelerated after vagotomy furthermore a lesser degree of stenosis then seems able to cause clinical evidence of obstruction.

If at laparotomy there is any suggestion of stenosis or threatened stenosis at the pylorus some form of by-pass operation should be undertaken at the same time as vagal resection

Vagotomy Plus Gastro-Jejunostomy

Gastro-Jejunostomy has proved very satisfactory so far but experience with this operation combined with vagotomy has been neither extensive enough nor long enough for it to be possible to say that no danger of late jejunal ulceration exists (Crile 1948 Orr and Johnson 1949)

Vagotomy Plus Antrectomy

An alternative procedure is to resect the ulcerated part of the duodenum and the gastric antrum, a third to one-half of the stomach being removed. After the duodenum has been divided the lesser curve of the stomach is straightened and measured from the cardia to the pylorus The midpoint may then be marked and the stomach resected to this level Owing to the shape of the stomach the area of the piece removed is then always less than half the total

The purpose of this operation apart from the removal of the ulcer itself, is different from that of gastrectomy when performed alone for duodenal ulcer the aim of the latter being to reduce acid secretion by ablating a large proportion of the acid-secreting oxyntic cells of the gastric mucosa. Antrectomy combined with vagotomy on the other hand, is intended to eliminate both neural and hormonal sources of stimuli to acid secretion, and so to permit a less extensive and dangerous gastrectomy than is usually thought advisable for the treatment of a duodenal ulcer

The Billroth I method of anastomosis in which the gastric stump is joined to the duodenum has been found unsatisfactory when combined with vagotomy as the relatively small stoma which it provides is inadequate when the gastric emptying force has been reduced by nerve section.

I now employ as a routine the Polya Hofmeister type of anastomosis with afferent loop to the lesser curve

It is too soon to say whether the rationale of vagotomy plus limited gastrectomy has been well founded and whether vagotomy will justify the routine use of a less radical gastric resection than is otherwise required for duodenal ulcer

Whenever the ulcer is found to be large callous or deeply penetrating or when there has been a history of bleeding, it is certainly wiser for the present to remove the ulcerated area and carry out either a limited or more classical resection at the same time as the vagi are divided

Before the anastomosis is completed the suction half of the special gastric tube is drawn down and passed bodkin fashion well up the afferent loop into the duodenum some of the suction holes being however still within the stomach The other half through which the patient is to be fed, is then passed down into the jejunum.

Refinement of the Operation

If adequate denervation of the acid-secreting areas can be achieved without it it is open to question whether denervation of the pylorus and the pyloric antrum is necessary or even desirable Furthermore the nerve supply to the pyloric region comes via the hepatic branches of the anterior vagus from which the pancreas is also supplied If this group of nerves could be preserved it is possible that hypoglycaemia might be avoided

It is also possible that the destruction of the large branch of the posterior vagus to the coeliac ganglion is unjustified and unprofitable. But dissection and preservation of these branches is very difficult and almost impossible without risk to the main sympathetic supply to the stomach which runs with the left gastric artery

Division of the sympathetic nerves may have the reverse effect from that desired and should certainly be avoided Their preservation seems desirable during gastrectomy too and therefore the left gastric artery is ligated no higher than is absolutely necessary during that operation

THE THORACIC OPERATION

Introduction

The main advantage of the thoracic approach it is claimed is that the vagus nerves are easier to find and resect by this route This has been said to result in a larger proportion of operations in which total vagal division is achieved All are agreed that the detection of every fibre is the greatest difficulty of the operation of vagotomy as is shown by the frequency of disappointment on post-operative insulin test. The latest evidence does not support the view that the thoracic operation is any more reliable in this respect than the abdominal one and further experience has shown that in some hands the abdominal approach is the more successful

The disadvantages of the thoracic operation are serious First and foremost is that it is a blind operation offering no opportunity for confirmation and proper examination of the lesion nor of ascertaining whether any further procedure should be undertaken

Introduction of Feeding Tube Before the abdomen is closed, one end of the special two-lumen tube is threaded well down into the small bowel for the purpose of feeding the suction half remaining in the stomach.

Modifications

Moore (1947) has recommended that after section of the vagi the cut ends of the nerves should be enclosed in silk sheaths turned upwards and sewn into a position well away from the distal ends to discourage regeneration. Weeks (1946) and Moore (1947) have both advocated injection of the nerves with procaine before section in order to block hypothetical afferent stimuli at the moment of division which it has been suggested, might cause reflex cardiac phenomena

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Added Operations

Healing of a duodenal ulcer is accompanied by the formation of scar tissue which may constrict the pylorus Though obstruction usually takes many years to become apparent its development may be accelerated after vagotomy furthermore a lesser degree of stenosis then seems able to cause clinical evidence of obstruction

If at laparotomy there is any suggestion of stenosis or threatened stenosis at the pylorus, some form of by-pass operation should be undertaken at the same time as vagal resection

Vagotomy Plus Gastro-jejunostomy

Gastro-jejunostomy has proved very satisfactory so far but experience with this operation combined with vagotomy has been neither extensive enough nor long enough for it to be possible to say that no danger of late jejunal ulceration exists (Crile 1948 Orr and Johnson 1949)

Vagotomy Plus Antrectomy

An alternative procedure is to resect the ulcerated part of the duodenum and the gastric antrum, a third to one half of the stomach being removed After the duodenum has been divided the lesser curve of the stomach is straightened and measured from the cardia to the pylorus The midpoint may then be marked and the stomach resected to this level Owing to the shape of the stomach the area of the piece removed is then always less than half the total

The purpose of this operation, apart from the removal of the ulcer itself is different from that of gastrectomy when performed alone for duodenal ulcer the aim of the latter being to reduce acid secretion by ablating a large proportion of the acid-secreting oxyntic cells of the gastric mucosa Antrectomy combined with vagotomy on the other hand, is intended to eliminate both neural and hormonal sources of stimuli to acid secretion and so to permit a less extensive and dangerous gastrectomy than is usually thought advisable for the treatment of a duodenal ulcer

The Billroth I method of anastomosis, in which the gastric stump is joined to the duodenum has been found unsatisfactory when combined with vagotomy as the relatively small stoma which it provides is inadequate when the gastric emptying force has been reduced by nerve section

I now employ as a routine the Polya Hofmeister type of anastomosis with afferent loop to the lesser curve

It is too soon to say whether the rationale of vagotomy plus limited gastrectomy has been well founded and whether vagotomy will justify the routine use of a less radical gastric resection than is otherwise required for duodenal ulcer

Whenever the ulcer is found to be large callous or deeply penetrating or when there has been a history of bleeding, it is certainly wiser for the present to remove the ulcerated area and carry out either a limited or more classical resection at the same time as the vagi are divided

Before the anastomosis is completed, the suction half of the special gastric tube is drawn down and passed bodkin fashion well up the afferent loop into the duodenum some of the suction holes being however still within the stomach The other half through which the patient is to be fed is then passed down into the jejunum

Refinement of the Operation

If adequate denervation of the acid-secreting areas can be achieved without it it is open to question whether denervation of the pylorus and the pyloric antrum is necessary or even desirable Furthermore the nerve supply to the pyloric region comes via the hepatic branches of the anterior vagus, from which the pancreas is also supplied If this group of nerves could be preserved it is possible that hypoglycaemia might be avoided

It is also possible that the destruction of the large branch of the posterior vagus to the coeliac ganglion is unjustified and unprofitable But dissection and preservation of these branches is very difficult and almost impossible without risk to the main sympathetic supply to the stomach which runs with the left gastric artery

Division of the sympathetic nerves may have the reverse effect from that desired and should certainly be avoided Their preservation seems desirable during gastrectomy too and therefore the left gastric artery is ligated no higher than is absolutely necessary during that operation

THE THORACIC OPERATION

Introduction

The main advantage of the thoracic approach, it is claimed is that the vagus nerves are easier to find and resect by this route This has been said to result in a larger proportion of operations in which total vagal division is achieved. All are agreed that the detection of every fibre is the greatest difficulty of the operation of vagotomy as is shown by the frequency of disappointment on post-operative insulin test. The latest evidence does not support the view that the thoracic operation is any more reliable in this respect than the abdominal one and further experience has shown that in some hands the abdominal approach is the more successful

The disadvantages of the thoracic operation are serious First and foremost is that it is a blind operation offering no opportunity for confirmation and proper examination of the lesion nor of ascertaining whether any further procedure should be undertaken.

Other bad features are the incidence of pleural effusions after operation with their attendant morbidity the longer convalescence usually required and the occurrence of troublesome pain in the scar

As previously stated, the thoracic operation is only indicated in a case of anastomotic ulcer after a Polya-type gastrectomy where there is good reason to believe that the peritoneal cavity has become largely obliterated by adhesions

Technique in Brief

Positive pressure anaesthesia is employed and the patient is placed on the right side with the left arm extended on a rest.

The chest is opened through the bed of the left eighth rib and the lung allowed to collapse sufficiently to expose the lower few inches of oesophagus The inferior pulmonary ligament is divided, the mediastinal pleura over the oesophagus is incised, the nerves are identified on back and front and a good length is resected.

The mediastinal pleura is repaired with a few interrupted stitches and the lung re-expanded before closure of the thorax without drainage Pleural effusion must be watched for and aspirated as necessary and prophylactic penicillin should be given post-operatively

POST-OPERATIVE MANAGEMENT AFTER VAGAL RESECTION

The immediate result of vagal resection is paresis of the stomach As with any paralysed muscle the first principle of treatment is that stretching of the muscle must be prevented until tone has returned The stomach musculature recovers intrinsic tone quickly but until it does so continuous gastric suction must be maintained Intermittent aspiration by syringe is inadequate as swallowed air as well as fluid must be prevented either from accumulating or from entering the bowel until the danger of ileus has passed. Fifty cubic centimetre drinks of water may however be given as desired provided they are re-aspirated at once An intravenous drip of saline with glucose is indicated until enough fluids can be given by other routes.

The passage of flatus or return of bowel sound on auscultation indicates that peristalsis is again present. As soon as bowel sounds can be heard feeding may be started via the jejunal tube and 50 c c of clear fluids may be given half hourly as long as no distension occurs The patient s girth should be charted in order that accumulation of fluids in the bowel may be detected at once As long as gastric suction is maintained salt should be given by one or other route at the rate of 5 to 10 gm per day

On the third day the continuous gastric aspiration is stopped and hourly emptying by syringe is substituted

Jejunal feeding is continued and at the same time 50 to 100 c c. of water is given by mouth, the stomach being emptied just before each feed.

If at the end of the day substantially less fluid has been aspirated than has been given by mouth showing that fluid is now passing satisfactorily into the small bowel the gastric tube may be withdrawn (If not then continuous aspiration should be re-established for a further period)

Two-hourly feedings are then allowed by mouth Milk drinks should continue

to be citrated and should alternate with broths jellies, and the like In the evening a Ryle or Levin tube should be passed to confirm that no significant gastric retention has occurred

Feeding is then cautiously increased day by day so that by the end of two weeks the patient is on fairly normal food, except that meals should still be rather small and the diet supplemented with nutrient drinks between meals Fibrous and cellulose foods are best avoided for a few months and the patient is warned not to take onions or soft fruit as these may initiate diarrhoea

The most frequent post-operative complication is pulmonary atelectasis and prophylactic measures are routinely employed against it.

POST-OPERATIVE INVESTIGATIONS

Just before the patient is due to leave hospital the secretion investigations are repeated in order that the completeness of the neurectomy may be assessed and its effects recorded.

Insulin Test

The result of the post-operative insulin test is particularly important, as an acid response to insulin hypoglycaemia indicates that the interruption of the vagus nerves has been incomplete As it may not be assumed that the same dose of insulin which produced a satisfactory hypoglycaemia before operation will also do so afterwards (Brook, 1948) the test should be controlled by a blood sugar estimation, best performed thirty minutes after giving the insulin.

The result of the insulin test is not always easy to assess after operation, for occasionally a slight response will appear to have occurred although before operation the response has been either well-marked or altogether absent.

Study of the spontaneous secretion curves shows how much succeeding specimens may vary even in the absence of any artificial stimulus and some of these apparent slight responses to insulin may therefore be spurious They should be read against the background of an all-night secretion curve for if this has been steady even a slight rise affecting only the curve of total acid particularly if it continues in succeeding specimens probably indicates that some vagal fibres have been missed Equivocal tests are repeated

Nine out of ninety patients failed to show any acid response to insulin *before* operation in the author's series absence of response after operation is therefore never an absolute proof of complete vagal division

X-ray Examination

A barium meal x ray examination should be carried out at the end of convalescence one month after discharge from hospital Apparent persistence of a crater at this time is less important than the finding of tenderness localised over it, for rapid healing of an ulcer near the pylorus may cause pouching and diverticulum formation which may simulate a crater though no tenderness can be elicited In two such cases which have come to reoperation for other lesions sound healing has been found.

Deformity of the duodenal bulb when due to scarring, is likely to increase

rather than diminish at subsequent x ray follow-up The radiologist shoul l also be asked to record the gastric emptying time any evidence of pyloric stenosis and any irregularities of motor function

FOLLOW UP AND RECORDS

Since the extensive use of vagotomy began only five years ago it must still be considered to be on trial It is most important therefore that the results and side effects be studied with great care and complete records and follow-up notes be accumulated Only when a sufficiently large number of completely and accurately studied cases are on record can they be submitted to proper statistical analysis and an authoritative statement on the long-term results be made

It is obviously desirable that during the experimental phase no patient should be submitted to this operation unless it is intended that full in estigations and records should be made to add to the common fund

Most important are an exact description of what was found at operation, what was done at operation, and what post-operative regimen was used Subsequentl the patient is seen at regular intervals and every care is taken to keep in touch with him for as many years as possible It is particularly important that the insulin test be carried out after operation and again after a few months Follow-up barium x-ray examination is also necessary with special reference to emptying time and abnormalities of gastric and duodenal motor function as well as to the progress of deformity and crater

In the follow-up period the known complications are specifically sought for and all results whether good or bad, honestly reported When a sufficiently large group has been followed for several years it should be anal sed by a trained statistician and published This is the clear duty of any surgeon prepared to take part in this or any other human experiment

RESULTS OF VAGAL SECTION

PHYSIOLOGICAL RESULTS

The agus is the motor nerve to the stomach muscle but intrinsic tone and peristalsis are possible after its division It is also the secreto-motor nerve and Alley (1933) has shown that vagal stimulation produces strongly acid secretion particularly in the region of the lesser curve of the stomach.

Pa lov established the role of the vagus in the psychogenic phase of gastric secretion, and Dragstedt has shown its importance in maintaining the flow of resting juice

The exact func tion of the agus for other abdominal organs is still uncertain and even the ultimate distribution of its fibres is still a matter of controversy

The physiological effects of agotomy in man ma be grouped as ga tric secretory gastric motor and extragastric

Effects on Secretion

Fractional analy is of gastri aspirations collected during and after operation show an immediat and marked diminution in olume of secretion and disappearance of free hydrochloric acid

In a few cases a little hydrochloric acid may again be present intermittently after about twenty four hours In a day or two there is a gradual rise in the proportion of titratable total acid present even in those in whom free hydrochloric acid does not reappear After fourteen days the total acid may be at a high level and there are organic acids present but free hydrochloric acid, if present at all is well below its previous level of titratable acidity There is a marked increase of buffering and an excess of mucus in the gastric juice

Routine investigation of the spontaneous night secretion two or three weeks after operation in forty patients showed a reduction by 77 per cent of the average of their free acidities, and 74 per cent in volumes The average pH before operation of the bulked night s secretion was 2 and after operation 4 7 (Johnson 1948b)

A few patients investigated again after intervals of two years or more have shown continued depression of night secretion in the great majority of cases while in some a further fall in resting acid secretion has been observed

A constant reduction has also been noted in the response to histamine and this effect has remained.

In no case so far has any return of insulin response been found where this had been shown, shortly after operation to have been abolished

The increase in buffering conspicuous for a while after vagotomy has not persisted nor does the copious production of mucus continue for very long

Motor Effects

The effect of vagal resection on *gastric emptying time* appears to be very variable Typically it is greatly prolonged but shows gradual recovery in the course of a few months In many cases a 6 or 8 hour delay is still observed after three or four months and there may be no further subsequent recovery In others gastric emptying time returns to normal quite quickly A few have recovered the excessively rapid emptying which they had shown before operation and this in spite of a loss of insulin response The question will naturally arise, however whether these also were cases of incomplete vagotomy

The mechanism of gastric delay is not so simple as it might at first appear to be for it cannot always be correlated either with a loss of peristalsis or with a reduction in gastric tone In fact in investigation of intragastric pressure/volume curves before and after operation, results have been very varied the pressure figures being often raised after vagotomy

There is frequently an increased volume of air in the stomach and this it has been shown experimentally may upset the mechanism of emptying

Although *pyloric spasm* has been several times reported as following vagotomy a *patulous state of the pylorus* is more usual This does not accelerate gastric emptying, which is still governed by the receptiveness of the duodenal bulb and the relation between intragastric and duodenal pressures It may however delay emptying, by allowing reflux into the stomach as the duodenal bulb contracts Such reflux has been seen in several patients *Loss of duodenal bulb contractility* is often observed In other cases the bulb does not fill well though the barium can easily be massaged through the pylorus suggesting that a disordered gastro-duodenal pressure gradient is at fault rather than a pyloric spasm

The excessive entry of gas into the stomach so often noted after vagotomy shows

itself by *repeated belching* and *passage of flatus* It would appear that there is increased air swallowing or that possibly owing to damage to the nerve supply of the cardia there is oesophageal pumping of air into the stomach

Extragastric Effects

One of the well-known effects of vagotomy is the *increased bowel activity* that results To what extent this is due to direct vagal denervation or to what extent it is due to some secondary effect such as the modified nature of the material leaving the stomach to an altered sensitivity to acetylcholine or to compensatory over activity of some other part of the vegetative nervous system remains at present an open question

Intestinal colic is an occasional complaint after operation, and as this is not always relieved by the passage of flatus it cannot be entirely blamed upon the increased entry of air into the bowel

The occurrence of *hypoglycaemic attacks* after vagotomy has been confirmed by blood sugar estimations in several cases but it cannot be correlated with the rate of gastric emptying I am inclined to the view that they occur because of destruction of the vagus supply to the pancreas resulting in disordered control of insulin secretion but can offer no evidence for this at present.

Whether the *night sweats* occasionally noted are also hypoglycaemic in origin has not yet been determined.

The Relief of Pain

It would appear to be established that pain stimuli from lesions of the stomach and duodenum travel by the sympathetic nerves, and Foerster (1927) has reported that only nausea is experienced when the proximal end of the cut vagus is stimulated electrically It is not therefore by severance of pain pathways that vagotomy relieves ulcer distress

Bonney and Pickering (1947) have illustrated how the level of hydrogen ion concentration in relation to the ulcer crater is the essential factor determining the onset of ulcer pain

It is certainly possible that vagotomy relieves ulcer pain by causing a sharp fall in hydrogen ion concentration What acid is secreted, furthermore is retained in the stomach and liberated more slowly into the duodenum, thus giving greater opportunity for its dilution by bile, pancreatic juice and succus entericus in the neighbourhood of the ulcer

This hypothesis is confirmed by finding that large doses of hydrochloric acid given by mouth shortly after operation cause the reappearance of ulcer pain

Walters and his associates (1947) reported the death of a patient thirteen days after vagotomy and gastro-enterostomy from subphrenic abscess said to have been caused by an unsuspected perforation However post-operative peritonitis is notoriously silent and there is no valid evidence that in this case the vagotomy had anaesthetised the peritoneum as suggested in this paper

It was pointed out by Aird (1935) that the relatively painless perforation which sometimes occurs in carcinoma of the stomach might be explained by the absence of hydrochloric acid from the escaping fluid This may also explain why a perforation

occurring just after vagotomy did not cause the more usual severe pain and rigidity A case of painless perforation after vagotomy and thoraco-lumbar sympathectomy was published by Weeks and Van Hoy (1946) but here the sympathectomy was almost certainly the cause of the peritoneal anaesthesia as well as possibly for the flare-up of the ulcer

I have seen a patient who had had a perforation before a vagotomy and subsequently another one Thi patient stated that his symptoms were exactly the same on the two occasions

CLINICAL RESULTS

The first clinical result of vagotomy is the immediate relief of ulcer pain However as such relief also follows the repair of a perforation only the continued control of ulcer distress may be regarded as significant.

The long term results are still awaited and few follow-ups over a year or so have yet been published The series of 215 operated upon by Orr and the author started five years ago but only 65 of these ha e been followed more than two years and 150 more than one year at the time of writing However the relatively short term results may be compared with the series of St John and Hood (1939) who found that 65 per cent of 225 duodenal ulcer patients treated medically had recurrences within two years and of Illingworth *et al* (1946) who report that 20 per cent of patients operated upon for perforated ulcers reperforated or bled within five years (See accompanying table)

Follow-up Program in Series of 215 Vagal Resections (Orr and Johnson)

O E HUNDRED A D EIGHT DUODENAL ULCER PATIENTS TREATED BY VAGOTOMY ALONE

	Number followed	Still symptom-free	Better but not symptom-free	No better or relapsed
82 *Insulin Negative* (Division possibly complete)				
Followed more than 6 months	71	54 (76%)	3	4 (6%)
" year	68	53 (78%)	1	4 (6%)
" 1½ years	52	38 (73%)		4 (8%)
" 2	30	9 (63%)	8	3 (0%)
2½	9	3 (68%)	5	(5%)
3	9	7 (77%)	1	(1%)
26 *Insulin Positive* (Division probably incomplet)				
Followed mor than 1 year	25	9 (36%)	3	3 (52%)
" 2 years	6	6 (37%)	—	(62%)
" 3	[illegible]	6 (60%)	—	4 (40%)

THIRTY-FOUR DUODENAL ULCER ATIENTS HA ING AGOTOMY AND GASTRO-ENTEROSTOMY

(Including 8 gotomies for recurrence after earlier gastro-enterostomy and 5 gastro-enter ostomies for pyloric stenosis after earlier agotomy)

Followed more than 6 months	29	25 (86%)	3	
" 1 year	21	18 (86%)	2	1
2 years	4	2 (86%)	1	
3	6	5 (83%)	—	

EIGHTY-THREE PATIENTS HAVING VAGOTOMY AND PARTIAL GASTRECTOMY

(Including vagotomies for recurrence after earlier gastrectomy and gastrectomies for failure after earlier vagotomy for gastric ulcer which failed to heal, for recurrence of haemorrhage, 4 with pyloric stenosis and 4 for relapse after incomplete vagotomies)

Followed more than 6 months	66	56 (85%)	9	
" year	36	29 (8[illegible]%)	6	
3 years	13	10 (77%)	3	

OPERATIVE MORTALITY

Vagotomy alone 13 operations 0 deaths
Vagotomy plus gastrectomy or gastroenterostomy 84 operations, death
Over-all mortality 2 5 operations, under per cent

PROGRESS IN TECHNIQUE

Incidence of failure to achieve complete vagotomy by criterion of insulin test.
First 15 operations, all incomplete
First hundred operations, 27 incomplete
Second hundred operations, 9 incomplete
Latest fifty operations, none incomplete

There is a proportion of patients, perhaps 75 per cent, who seem to be altogether symptom-free after simple vagotomy and who have remained so at least for the year or two that they have so far been followed up.

A small group are not completely relieved of dyspepsia but have attacks of less severity, shorter duration, and much less frequency.

Another group are cured of their ulcer distress but have instead intestinal colic of almost equal severity and cannot be said to be greatly improved symptomatically.

Lastly there are a few patients who seem no better at all for their operation. Among these are included some whose vagotomies have been incomplete, also some whose personality make-up was such that it is unlikely that any operation would have improved them, some who had gastric ulcers, and some who had pyloric stenosis. Nearly all failures of these latter kinds must be attributed to the selection of unsuitable patients for vagotomy.

By no means all cases of apparent incomplete vagotomy turn out failures, though the proportion of successes among them is lower. It is interesting to note, however, that the incidence of complications is also lower in this group and several of the most brilliant successes have been amongst them.

The results of vagotomy combined with gastro-enterostomy or partial gastrectomy are difficult to assess as the other operation may be claimed to be wholly responsible for such cures as are achieved.

So far vagotomy plus gastro-enterostomy has been followed by good results in the small group followed up by the author, but it is still too soon to say that no danger of later jejunal ulceration exists.

A combination of gastrectomy and vagotomy was advocated by Winkelstein and Berg (1938), and a more conservative resection than that necessary when used alone for duodenal ulcer is being practised by some at the present time.

Most surgeons are agreed that the result of vagotomy for anastomotic ulcer are good, and many now consider it the treatment of choice in this condition (Allen, 1947; Maingot, 1948).

COMPLICATIONS

The complications of vagal resection may be classified as immediate or late. Their incidence in a series of 131 cases where vagotomy has been used alone is given in the accompanying table.

Complications

POST-OPERATIVE COMPLICATIONS

	PER CENT
Operative mortality	
Atelectasis, sufficient to cause physical signs	5
Transitory dysphagia	15
Transitory diarrhoea	15
Gastric retention requiring rather prolonged aspiration	3
Ileus of the large bowel	2

No severe post-operative complications have occurred in this series except one case of empyema following transthoracic operation.

EARLY SYMPTOMS RESULTING FROM VAGOTOMY (LASTING LESS THAN 3 MONTHS)

Hypoglycaemic symptoms, occasional or slight	50
Flatulence	33
Wind pain, occasional or slight	10
Offensive belching	9
Occasional morning vomiting	7
Short recurrent attack of diarrhoea	5

MORE PERSISTENT SYMPTOMS

Hypoglycaemic attacks	9
Wind pain	5
Repeated attacks of diarrhoea	4

IMMEDIATE COMPLICATIONS

Cardiac Effects

A sudden death which occurred during the operation was ascribed by Weeks and his co-workers (1946) to an effect upon the heart of manipulating the vagus nerves. For this reason he and also Moore recommend the injection of procaine into the nerves before their division.

On the other hand, in my own experience I could detect no electrocardiographic changes during vagal resection.

Acute Dilatation of the Stomach

Gastric dilatation has been described as a complication during the immediate post-operative period (Walters *et al.* 1947). Such a complication should be impossible if the routine of management here laid down is followed.

Ileus of the Colon

Dilatation of the large bowel is an uncommon complication of vagotomy which has occurred in three of my cases. The colon becomes greatly distended with gas, which causes considerable discomfort or pain and may force the diaphragm upwards sufficiently to embarrass respiration. Though some flatus continues to be passed spontaneously, a flatus tube does not appear to facilitate its escape. The condition is

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3 years	3	1 (77%)	2	

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Vagotomy plus gastrectomy o gastroenterostomy 84 operations, death
Over-all mortality 2 5 operations, under 1 per cent

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believed to be associated with air swallowing, and this in turn may result from damage to the nerve supply of the cardia It does not occur so long as the stomach is being kept empty of both fluid and gas by continuous aspiration

The condition may suddenly subside or it may require treatment with repeated doses of pituitrin Eserine increases the pain and does not relieve the distension

Pulmonary Collapse

Post-operative atelectasis occurs sufficiently frequently to justify its consideration as a special complication of this operation

Fig 81 X-ray with barium swallow of a patient with dysphagia six weeks after vagotomy Note the presence of air in the stomach not seen in established cases of achalasia.

Prophylactic treatment consists in teaching the patient breathing exercises before operation avoidance of deeper anaesthesia than is necessary for the proper performance of the operation sparing use of morphia or other respiratory depressants after operation, resumption of breathing exercises on recovering consciousness, and encouraging the patient to cough

Dysphagia

Slight dysphagia is a not infrequent symptom for a few days after operation and may be traumatic in origin

An uncommon complication is that of true cardiospasm (Fig 182) It clears up spontaneously in a few weeks or may be relieved by the inhalation of octyl nitrite before meals

LATE COMPLICATIONS

Chronic Gastric Retention

Dragstedt maintains that chronic gastric stagnation can be avoided if sufficient care is taken in rehabilitating the stomach after operation

The effect of vagotomy on gastric emptying varies considerably

If gastric delay is excessive the patient may have symptoms the belching of foul smelling gas being the most troublesome Excessive belching is not in itself a symptom of retention but indicates that an abnormal volume of air is finding its way into the stomach It is frequently noticed for a few weeks or months after vagotomy and may be due to injury to the mechanism of the cardia.

A less common complaint is that of occasional vomiting In contrast to that of pyloric stenosis the vomiting typically occurs first thing in the morning on rising Gastric retention unless due to scarring at the pylorus tends to disappear in a few months

The Hypoglycaemic Syndrome

A substantial number of those patients whose vagotomies appear to have been complete on insulin test subsequently experience attacks of faintness sometimes accompanied by trembling and sweating The attacks which last about twenty minutes usually come on in the afternoon an hour or two after the last meal and may be precipitated by exercise They appear to be due to hypoglycaemia and respond to sugar or ephedrine (Johnson, 1948b)

In many cases the attacks are transitory and clear up after a week or two In others they persist or recur

Some patients mention only that they seem to tire more easily than previously and others notice only an increased tendency to sweat, sometimes experiencing drenching night sweats Whether these symptoms are also related to hypoglycaemia is not yet established.

Diarrhoea and Colon Colic

Diarrhoea is another complication which is mostly confined to those with no post-operative insulin response and particularly when achlorhydria develops It is nocturnal as well as diurnal and may be very troublesome It may commence a few days after operation last only a day or two and then clear up completely or it may persist for weeks or even months

Diarrhoea also tends to return in brief attacks which may be preceded by or accompanied by fairly severe large bowel pain

Food by stimulating the gastro-colic reflex, may initiate the onset of the spasms so that the attacks may resemble recurrences of ulcer pain. Particular foods especially onions may precipitate an attack

Some patients complain of wind pain without diarrhoea.

The diarrhoea can usually be controlled by sulphasuxidine or sulphaguanidine and kaolin or chalk is often effective

Of the many patients who had suffered from constipation before vagotomy all but one were completely relieved. However the constipation has returned in three cases within eighteen months

Gastric Ulcer

In an earlier publication I anticipated that gastric ulcer might prove to be a late complication of vagotomy in man (Johnson 1947) Since then four cases have come within my experience Two of these were patients with combined ulcer in whom *the duodenal ulcer healed after vagotomy but the gastric ulcer progressed* and became larger In the other two the gastric ulcer appeared *de novo* a few months after vagal resection and enlarged to considerable size and depth. It is most important to note however that in neither of these patients had complete vagotomy been achieved as shown by their insulin response. In all four patients night secretion investigations had shown neither the very copious nor the very acid secretion found typical of duodenal ulcer patients in my series

Mortality

Among a group of over 300 patients submitted to vagotomy or combined operations by the author and his colleagues at several London hospitals, the operative mortality has been nil Isolated instances of death which have been published in America have nearly all followed more complicated and dangerous operations in which vagotomy was only a step

There is little doubt that the operation of vagal resection by the abdominal route, performed with ordinary skill and in proper circumstances carries almost no risk to life

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CHAPTER 12

The Management of Acute Intestinal Obstruction

IAN AIRD

AFTER CONSULTING textbooks and contemporary surgical literature the reader forms the impression that the treatment of acute intestinal obstruction is now standardised and simple and that all dangers have been cleared from this difficult subject since the introduction of saline drip infusion and gastro-intestinal suction drainage It is part of my duty in this chapter to suggest that these two measures indispensable as they are, do not in practice form the effective armoury against intestinal obstruction that they appear to do on paper The perusal of case records of patients suffering from intestinal obstruction in any large teaching hospital makes it clear that in most cases though lip service is paid to saline drip infusion replacement of water and salt is almost nowhere governed by any mathematical principle and that fluid and electrolytes given by this means are inadequate; a number of deaths will occur from simple intestinal obstruction. Passing from the record files to the wards the observer is impressed with how relatively ineffecti e gastro-intestinal suction is The various forms of syphon tube readily passed as they are along the small intestine of the normal patient seldom negotiate the pylorus of the obstructed patient and this method of intestinal decompression is in general hands, much less satisfactory in practice than on paper In general surgical practice I have been more impressed with the difficulties of management of patients suffering from intestinal obstruction than with the success of textbook methods of therapy My contribution to this book may therefore seem disappointing, for I shall do more to explain failures than to suggest successful methods of correcting them

DIAGNOSIS IN INTESTINAL OBSTRUCTION

PRESENCE OR ABSENCE OF OBSTRUCTION

The essential feature of the management of a patient suffering from acute intestinal obstruction is the ac urat assessment before operation of his abdominal and general

ate. It must preferably be known whether or not the patient is completely obstructed, at what level the obstruction lies, what is the actual nature of the obstructing agent, and whether any element of strangulation is present.

Diagnosis of the presence of complete intestinal obstruction is not always as simple as one would wish. Colic, vomiting, absolute constipation and distension, the four cardinal signs of intestinal obstruction, need not always be present together. There may be no colic, for example, in paralytic obstructions; vomiting is delayed in low obstruction; constipation cannot be easily determined if the obstruction is of recent onset; and distension may be of slight degree if the obstruction is high.

Fig. 183 Gaseous distension of obstructed small intestine. Note transverse disposition, central situation and valvulae conniventes.

Diagnostic Enema Plus Scout Films

The result of a diagnostic enema is often equivocal, especially if that result is reported by word of mouth. More often one is told that the enema is returned "slightly stained" or "with a little flatus" than that it has been returned clear without flatus. Radiological signs of obstruction are of value in this regard. Normally the gaseous content of the small intestine is so widely dispersed that it shows no radiological shadow; the colon, however, may normally present a radiologically visible collection of gas. The colon below the obstruction may contain gas in as great amount as the colon above the obstruction. If the small intestine loops are shown to contain radiologically visible amounts of gas (Fig. 183), there is a strong probability that an obstruction is present. Diagnostic enema, combined with these radiological features, is of immense value. The gas normally present in the colon

can be evacuated by enema If gas remains present in any part of the colon (Fig 184) after diagnostic enema a colonic obstruction is present If loops of small intestine are shown to contain gas and if they continue to contain gas after the colon has been emptied by diagnostic enema, there is a complete obstruction of the small intestine A combination of diagnostic enema and of scout film thus gives *incontrovertible evidence of complete intestinal obstruction* If no gas shadows are present in the abdomen after diagnostic enema it may be presumed that no complete obstruction is present Incomplete obstructions give less definite clinical and radiological signs, for in these gas may be seen in loops of bowel both above and below the level of obstruction and gas evacuated by enema may be quickly replaced by gas from above the point of partial obstruction.

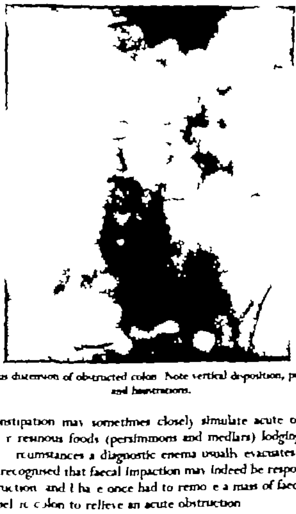

Fig 184. Gaseous distension of obstructed colon Note vertical deposition, peripheral situation, and haustrations.

Extreme constipation may sometimes closely simulate acute obstruction Impacted faeces or resinous foods (persimmons and medlars) lodging tightly in the colon In such circumstances a diagnostic enema usually evacuates faeces and gas but it must be recognised that faecal impaction may indeed be responsible for acute intestinal obstruction and I have once had to remove a mass of faeces like a tennis ball from the pelvic colon to relieve an acute obstruction

DISTINCTION BETWEEN OCCLUSION STRANGULATION AND ILEUS

Some part of the present mortality of acute intestinal obstruction is due to the failure to recognise the presence of strangulation and to continue to treat conserva-

tively a patient who should be submitted to operation almost at once Strangulation requires immediate operation, occlusion is best treated conservatively in the first instance and paralytic ileus seldom requires operation at all

There are four classical methods of distinguishing between the three types of intestinal obstruction—the character of the pain the presence or absence of rebound tenderness the presence or absence of rigidity and the presence or absence of leucocytosis, but these are all fallible in certain circumstances and I would like to add to them a fifth the effect of deflation on pain

In both occlusion and strangulation there is *pain* but the pain of strangulation is more severe and its spasms are more frequent than that of simple occlusion Overwhelming pain in a patient suffering from obstruction with spasms returning several times a minute is very suggestive of strangulation

Rebound tenderness is usually regarded as the chief criterion of strangulation In occlusion the site of obstruction is sometimes tender to pressure the point where the bowel is crossed by a constricting band for example or the site of an inflamed tumour but tenderness of this character is relieved when the examining hand is raised from the abdomen again In strangulation the affected loop is always tender but tenderness is elicited also when the examining hand is raised from the abdomen again

Rigidity is not usually present in any degree but if it is present it suggests strangulation

A high *leucocytosis* is not conclusive evidence of strangulation distension of the bowel alone may produce a leucocytosis of over 20 000 We do not practise aspiration of the peritoneal cavity to assist in the distinction between occlusion and strangulation paracentesis of the abdomen might carry a high risk if intestinal distension were considerable

To my mind the clearest differentiation between occlusion and strangulation is to be obtained by observation of the *effect of deflation on the patient s pain* If after the establishment of effective gastro-duodenal suction drainage pain is still severe and unrelieved after two hours it may be assumed that strangulation is present

If the actual nature of the obstruction can be deduced it sometimes indicates the type of obstruction present—occlusion or strangulation External hernia volvulus intussusception and mesenteric vascular occlusion can be diagnosed with fair accuracy and imply the presence of strangulation The differentiation of strangulation from simple occlusion is particularly difficult in adhesive obstruction and in cases of internal hernia, which may produce a simple occlusion on one occasion and a strangulation on another

Paralytic ileus need not usually be considered except in post-operative obstruction Spastic ileus from a continued spasm of a segment of bowel can often be recognised from a history of ingestion of some irritant material or from the presence of disease in the central nervous system It resolves with conservative measures and antispasmodics and is seldom continued for long enough to be seriously mistaken for organic disease A scaphoid abdomen sometimes associated with bradycardia is suggestive of spastic ileus but I have known a bradycardia of 50 after twelve hours of strangulation

Internal hernia cannot often be differentiated from other forms of obstruction

but sometimes there is a tense localised tympanitic swelling If internal hernia is suspected to be the cause of obstruction operation must be undertaken relatively early as soon as the patient s fluid requirements have been to some extent answered.

LEVEL OF OBSTRUCTION

The level of obstruction is not of merely academic interest. It sometimes governs the management In high obstruction, the x ray may show very little in the way of gas-distended loops but the early copious and continued vomiting of high obstruction can hardly be mistaken for anything else Very seldom is high obstruction due to strangulation It may nearly always be safely settled by suction, and by the replacement of fluid and salt

It is important to recognise colonic obstruction, for the long-continued conservati e management of a distended colon may be dangerous If the ileo-caecal valve remains competent, colon distended between obstruction and ileo-caecal valve and the caecum may perforate Gastro-duodenal suction has only a limited application, therefore in colonic obstruction, and operation should be undertaken early The level of a colonic obstruction is clearly shown in most cases by x-ray the colon remaining outlined by gas after diagnostic enema Low rectal obstructions are, of course detected by rectal examination.

CAUSE OF OBSTRUCTION

The cause of obstruction can often be deduced and may be a clear guide to clinical management. A tender external hernia for example means the threat of strangulation, and requires early operation. A ballooned pel ic colon is suggesti e of olvulus and operation is again indicated in most cases The passage of blood from the bowel together with the signs of obstruction and of rapidly increasing shock and circulatory failure in a patient who suffers from heart disease or ad anced arterio-sclerosis or aneurysm is highly suggesti e of mesenteric vascular occlusion Intussusception, which requires immediate operation cannot be mistaken for any thing else if the patient is a lusty boy a few months old with a history of sudden pain and the passage of blood but even in the rare adult cases when intussusception is usually secondary to simple tumour its sausage-shaped swelling is highly characteristic If the patient is a stout middle-aged woman with a dyspeptic history and with previous recurrent attacks of threatened obstruction gall-stone ileus may be suspected and may sometimes be recognised by the shadow of an opaque calculus in the x ray lying among gas-distended loops an impacted gall-stone quickly produces necrosi of the bowel loop in which it lies, and operation should not be postponed for too long

The *age of the patient* often gi es some hint of the cause of the obstruction. Atresia is usually the cause of obstruction present at birth volvulus neonatorum causes obstruction a few days or weeks after birth In the second and third months incarcerated hernia is usually to blame and from the third to the twelfth month, intussusception In late childhood plastic tuberculosis is often responsible and in early adult life strangulated hernia begins to be met though tuberculosis of bowel or peritoneum comes into the pi ture now Men in the 30 s and 40 s are liable to strangulated inguinal hernia women in th 40 s or later to strangulated femoral or umbilical hernia or to gall-stone ileus and in the later age-periods cancer of the colon is the commonest cause of obstruction, and strangulated external hernia only second in importance

At any age an operation scar may suggest adhesive obstruction and it is in these cases particularly that it may be difficult to distinguish between occlusion and strangulation for a tight adhesion which may produce either occlusion or strangulation, may give rebound tenderness in either of these circumstances

GENERAL MANAGEMENT OF ACUTE INTESTINAL OBSTRUCTION

There are three measures available for the treatment of intestinal obstruction—gastro-duodenal suction intravenous fluid administration and operative correction Given early diagnosis success in treatment depends upon the prompt commencement, the efficient management and the adequate continuation of the first two of these and the choice of a proper moment for the third *

When a diagnosis of simple occlusion of the small intestine has been confidently made and when strangulation has been definitely excluded gastro-duodenal suction-drainage is established, the patient s requirements of water and salt are estimated and intravenous fluids are given in suitable amounts and proportions to restore the fluid balance in twenty four to forty-eight hours A fluid balance chart is kept, and the degree of distension is estimated repeatedly and many times daily by inspection and measurement of the abdomen by tape and a daily x ray is taken to show the behaviour of the gas shadows If the patient s pain and distension both decrease on this management and provided the assumption that there is no strangulation present is correct water and salt loss is made good gradually and operation may be delayed almost indefinitely Paralytic obstructions are completely relieved by this treatment Some adhesive forms of occlusion may also resolve and make it possible if distension is relieved for the tube to be clamped for three or four hours at a time If when the tube is clamped, there is no discomfort no distension and no vomiting, the tube may be withdrawn to be replaced if pain, vomiting distension or x ray shadows of gas reappear

If severe pain persists for more than two hours after the establishment of effective gastro-duodenal suction it should be assumed that the diagnosis of occlusion has been wrong, that strangulation is present or threatened and that operation is desirable

Colonic obstructions are treated by early operation (see above) fluid loss is not great in these and can be quickly compensated and operation should be undertaken early to anticipate overdistension of the closed loop between ileo-caecal valve and obstructing agent

Blood transfusion is of particular advantage in extensive strangulations such as mesenteric thrombosis and embolism.

Strangulation is treated by early operation, which is delayed only until a duodenal tube has been passed and an intravenous drip of saline (or of blood if the strangulation is extensi e and shock considerable) The only form of strangulation which is sometimes managed without operation is mesenteric vascular occlusion

GASTRO-DUODENAL SUCTION

One would imagine from a consideration of the literature that to empty the distended bowel by a nasal or oral tube is a simple procedure We have not in practice found it to be so We have never had any difficulty in passing a Miller Abbott tube

* A d, I (949) *A Companion in Surgical Studies*. Edinburgh, E. & S Livingstone Ltd

throughout the whole length of the small intestine in a patient who is not obstructed Suction drainage is easy to establish for example before operation on the colon, when it is hoped to serve after operation as a preventive of deflation In acute intestinal obstruction however the tube seldom in our hands succeeds in passing the pyloric canal We have tried all the standard modifications of technique to overcome this difficulty We have used a whip-lash of catgut, we have used a mercury weighted tube and changes of the patient s position and we have used a bag of lead shot. We have not yet had recourse to a stiffening of piano wire or to the use of a steel tipped tube and an electro-magnet.

It is commonly assumed that the difficulty which the tube encounters at the pylorus is due to distension of stomach and duodenum and an increase in the angle at the pyloric canal. We have reason to suppose however that the real difficulty is of a different character On two occasions we have introduced a Miller Abbott tube at laparotomy undertaken for relief of distension in a patient suffering from adhesive obstruction. In both of these cases we have guided, by manipulation within the abdomen the tip of the tube through the duodenum into the first loop of jejunum and on both occasions we have found at the end of the operation that the *tube has returned to the stomach again In intestinal obstruction the highest intra*-intestinal pressure is in the lowest loop of distended bowel and the hydrostatic pressure within the bowel lessens disto-proximally on suction A tube attempting to negotiate distant gut must pass against the stream of intestinal content from a low pressure to a higher pressure As soon as a loop is emptied by suction it immediately fills again by fluid from below Similarly when a tube succeeds in emptying the distal stomach it cannot negotiate the pylorus because of a rush of fluid from the duodenum *back into the stomach. To this we ascribe our lack of success in the* passage of the intranasal tube in patients actually suffering from acute intestinal obstruction, and the greater the need for deflation the more difficult is it to pass the tube To some extent the disto-proximal flush of fluid can be turned to advantage in that a tube whose tip lies in the stomach, by keeping the stomach continuously empty will to some extent deflate the upper coils of small intestine in an indirect way We therefore depend on the tube largely to reduce gastric distension, at least in mechanical obstructions In paralytic obstruction the tube usually passes well, and effecti el deflates the small intestine We a oid, so far as possible the use of an *indwelling tube in infants because of the risk of the development of otitis media*, though it is doubtful to what extent the tube itself can be blamed for otitis media occurring in these babies it is a common complication of dehydrated babies whether they are treated by indwelling tube or not.

WATER AND SALT REPLACEMENT

We have found in general that, in the past the amounts of water and salt we have gi en patients in acute obstruction ha e been inadequate and we have tried to arri e at an arithmetical dosage scale for obstructed patients By careful water and salt balance we ha e been able to deduce the water and salt debt of our dehydrated patients It is relati ely easy to work this out by following the Fluid Balance Charts backwards from the final hydrated state of the convalescent patient (when urine is *secreted in satisfactory amounts and the weight has returned to normal*) to what the water and salt debt has been earlier at the time of admission. Our figures

correspond substantially with those of Abbott in America and of Marriott in this country. We can now say with some confidence that a 70-kg. patient who shows all the signs of dehydration, dry mucous membranes and oliguria, has sustained a water loss of some 4 litres. A patient who has been obstructed, who is distended or who has vomited, but who does not yet show clinical signs of dehydration, we assume arbitrarily to have sustained a loss of 2 litres. When such a patient is admitted we compute his fluid needs for the succeeding twenty-four hours. If he is clinically dehydrated he will, for example, require 4 000 c.c. to replace his lost fluid, 1 500 c.c. for urine, 500 c.c. for insensible loss from skin and lungs, and a certain amount of fluid to be withdrawn by suction. This last amount can be assumed to be 3 000 c.c. if suction drainage is effectively established. In the course of twenty-four hours this patient will, therefore, require 9 000 c.c. To obtain the drip-rate per minute we multiply the number of litres per day by 11. The budget for the patient we are considering will be balanced by a drip-rate of 99 drips per minute. It may be argued that our figure for insensible loss is low, and most of the textbooks compute insensible loss by skin and lungs to be 1 litre per day. Our fluid balance studies show that the dehydrated patient at rest in bed in a hospital ward loses substantially less than this amount, and probably 400 to 500 c.c. is an adequate allowance for this component.

The amount of salt given with this fluid is, of course, of high importance, and we have found that Marriott's rule to give the necessary fluid as half-strength saline rather than as normal saline answers most clinical purposes well. An alternative dosage can be obtained by estimating the chloride need precisely. In the patient we have just considered, who is assumed to have lost 4 litres of intestinal juice, the salt lost with that juice will be 0.5 per cent of 4 litres, or 20 gm. The salt needs for a patient at rest amounts to 3 gm. per day. A loss of 3.5 litres of intestinal fluid by suction will require a further 17 gm. of salt, and the patient who is dehydrated and shows the signs of dehydration will therefore require in all $3+20+17.5$ or 41 gm. of salt. This can be expressed as 4.5 litres of normal saline. Our patient will therefore have, in his first twenty-four hours of surgical management, 4.5 litres of normal saline and 5 litres of 5 per cent dextrose in water. The use of dextrose in this way avoids overloading the patient with salt and avoids also any risk of oedema provided the kidneys are healthy.

This amount of fluid during twenty-four hours looks rather alarming when expressed in cold figures, but in practice it can be shown to be entirely safe provided the salt dosage is not overestimated. It is only in the rather elderly patient that there is any risk of overdosage, and it is in these, and in younger patients with kidneys known to be diseased, that a close watch must be kept on the jugular venous pressure, on the subcutaneous tissues of the extremities, and on the bases of the lungs. Even the patient with diseased kidneys gives no anxiety during the first twenty-four hours of a dosage such as I have calculated here. We have had a number of patients who have developed anuria from the hypotension of late intestinal obstruction, and none even of these has become oedematous from a saline dosage computed in this way.

During his first and subsequent days the patient is kept, of course, on a careful Fluid Balance Chart, and it is easy, after the first day when precise figures have been kept, to budget at the end of each twenty-four-hour period for the needs of

1

the subsequent day It can be assumed at the end of each day that the fluid withdrawn by suction on the subsequent day will be of the same amount as the fluid withdrawn on the day just passed

There are several practical points in the keeping of a Fluid Balance Chart which are learnt only by experience The first is that the chart must be kept as simple as possible and we record only the water and salt intake and output. We have found the blood chemistry to be of no assistance in the assessment of dehydration, or in the computation of intravenous dosage we have known a patient to die from pyloric stenosis with a blood chemistry virtually normal It is sometimes surprising to find the urine fluctuate enormously in amount from day to day This is usually due to the patient passing a large quantity of urine either just before or just after the end of a twenty-four hour period It is wise to make a rule that each patient empties his bladder just before the end of a day In the management I have outlined it will be found that the patient when he returns to clinical hydration will be computed to be mathematically hydrated by the fluid balance charts

THE OPERATION FOR ACUTE INTESTINAL OBSTRUCTION

Anaesthesia

The anaesthesia employed in acute intestinal obstruction is of some importance. In general, spinal anaesthesia is not without danger though it is often a convenience for the operator There is some experimental evidence that in the muscular over activity of the bowel which follows spinal anaesthesia, too sudden a restoration of circulation may occur in obstructed and cyanosed bowel and clinically in man, death sometimes occurs suddenly during or after operation, when a spinal anaesthetic has been used for the release of an obstruction. The chief value of spinal anaesthesia was that it used to avoid the inhalation of vomitus which was so common a catastrophe at the end of operation when the early forms of general anaesthesia were employed. There should be no risk now of inhalation of gastric content if a patient is thoroughly prepared by a gastric suction before operation, and afforded the benefits of modern general inhalation anaesthesia. The fine relaxation which spinal anaesthesia used to provide is available to us now with curare, and intratracheal nitrous oxide and oxygen anaesthesia supplemented by intravenous curare is in my opinion the safest form of anaesthesia in acute intestinal obstruction.

Incision

The incision should be placed so as to afford ready access to the anticipated site of obstruction A herniotomy incision, of course will be employed for strangulated hernia For most other obstructive lesions a right paramedian incision, with splitting or displacement of the rectus muscle will be found adequate

Ascertainment of the Level of Obstruction

When the abdomen is opened every effort should be made to avoid withdrawing distended bowel into the operation wound when exposed to the atmosphere distended bowel not only loses fluid rapidly but relieved from intra-abdominal pressure proceeds to dilate still further sometimes almost visibly gas passing from the distended mucosal vessels into the lumen. To avoid the withdrawing of distended gut, the hand is passed first to the ileo-caecal region If the ileum is found

collapsed It is followed upwards until the point of obstruction is reached If the ileum is distended the lesion is in the colon The caecum is palpated first and the cause of the obstruction may be found there If however the caecum is distended the hand is passed to the pelvic colon If that is ballooned the causative lesion is in the rectum or recto-sigmoid If the pelvic colon is collapsed the hand palpates the transverse colon, and the level of the colonic lesion is then obvious

Determination of the Viability of the Bowel

The causative obstruction is now relieved and it is decided whether there is any threat to the vitality of the obstructed bowel particular attention being paid to any constriction ring At this point the anaesthetist floods the lungs with oxygen; it is impossible to decide the viability of bowel if the patient is suffering from general cyanosis and oxygenation effects a rapid return of colour in viable bowel The classical signs of viability still hold A bright pink colour or a pale pink colour is safe and usually there is not much danger in returning a blue bowel to the abdomen but other colours, notably black, green and purple signify infarction Peristalsis should pass freely from obstructed to non-obstructed bowel and pulsation should be present not only in the main mesenteric vessels but also in the peripheral mesenteric arcades Such gross signs as a foul odour and a consistence of wet blotting paper hardly need mention.

Short-Circuiting Operations

If it is impossible to remove the obstructing agent, some short-circuiting operation is performed. In the case of the small intestine this takes the form of a lateral anastomosis In the large intestine it is unlikely that an attempt will be made to remove a malignant tumour in the face of acute intestinal obstruction, and a drainage operation is established either as a temporary measure to prepare the patient for later excision, or in inoperable tumours as a permanent palliative procedure

POST-OPERATIVE CARE

The gastric suction and intravenous saline begun before operation, are continued after it. Even though an obstruction has been removed gastric suction is maintained until flatus has been passed by the bowel and until the suction tube can be clamped for several hours without return of distension or vomiting No pharmacological methods are undertaken to renew peristalsis after the release of an intestinal obstruction peristalsis will return normally provided the intestine is prevented from distending provided water and salt balance is maintained and provided the patient's protein requirements are fulfilled

SPECIAL VARIETIES OF OBSTRUCTION

Obstruction by Adhesions and Bands

Obstruction by adhesions and bands can often be relieved by gastro-intestinal suction without the need for operation and an abdominal scar in a patient with acute obstruction is often a sign for delay in operating Such a patient treated conservatively requires however to be most carefully watched for it is particularly in adhesive varieties of obstruction that the distinction is most difficult between strangulation which needs early operation, and simple occlusion which does not

It is in these patients particularly that a close watch must be kept during the maintenance of gastro-duodenal suction for any return of pain. Severe pain, persisting or increasing in spite of effective gastro-duodenal suction drainage is the clearest evidence we have of the presence of strangulation and of the need for early operation.

Obstruction by Enteroliths and Foreign Bodies

Obturation by enteroliths and foreign bodies seldom offers operative difficulty. Many obstructing agents of this kind may be disintegrated by the fingers without the need for opening the bowel. I have known a foreign body to lodge tightly in a stricture of bowel, and when a foreign body has been removed or otherwise disturbed, it is wise to inspect the bowel closely in case the prime reason for lodgment has been a pathological stricture.

Gall-stone Ileus

Gall-stone ileus offers many problems to the surgical theorist. It is peculiar how seldom the women who suffer from gall-stone ileus give a history of previous serious gall-bladder trouble. Though the gall-stone usually passes from gall-bladder to small intestine by way of a cholecysto-duodenal fistula, it is exceptional to obtain the history of a previous attack of cholecystitis. It is not uncommon, however, for the final acute obstruction to be preceded by a few or several attacks of subacute obstruction, from which the patient has spontaneously recovered. It would seem that the gall-stone in passing down through jejunum and ileum gets temporarily held up from level to level before finally reaching and impacting in the narrow lumen of the lower ileum.

It is perhaps because the patient is accustomed to recover from these "prodromal" attacks of colic that she usually presents so late to the surgeon, and it is remarkable that this, perhaps the simplest and most mechanical of all obstructions, should carry as high a mortality as any. The patient is usually an old lady, older than most of the patients who present with cholecystitis, and is not infrequently obese. I have not found much radiological help in the diagnosis of this condition; the obstructing gall-stones which I have removed have uniformly caused no radiological shadow. *At operation, the surgeon should not cut down precipitately on the stone* at the point where it has lodged; it is wiser to pass the stone upwards into the distended but viable bowel above before crushing it with the fingers or removing it by enterotomy. There is often considerable necrosis at the site of actual lodgment of the stone. Sometimes it is impossible to dislodge the stone from the point of its impaction; a small incision may then be made in the bowel above for the introduction of a lithotrite, which crushes the stone in situ.

Intussusception

Intussusception is too wide a subject for full consideration in a chapter devoted to the general aspects of intestinal obstruction. I shall content myself with saying that hydrostatic methods of reducing an intussusception have not commonly been applied by us to the common infantile variety, but they have been found of great value *in adult forms which are usually of a more subacute character. Resection* of irreducible or non-viable infantile intussusception is a much less serious operation

than it formerly was. At the Royal Hospital for Sick Children in Edinburgh there have now been more than twenty survivals after resection and the mortality for resection for irreducible or non-viable intussusception there has fallen from 1e per cent to 10 per cent in the last twenty years. This improvement in the fatality rate has been most beneficial. In the old days every effort was made to reduce an intussusception, and sometimes great force was employed to avoid resorting to an almost uniformly fatal resection. No hesitation is felt now in proceeding to resection if an intussusception proves irreducible after the employment of gentle manipulation.

Volvulus of the Pelvic Colon

The treatment of volvulus of the pelvic colon has not greatly altered in the last twenty years. It is still customary to pass a stomach tube up from the rectum before operation, for this simple manoeuvre sometimes undoes a slack volvulus. At operation, too, a rectal tube is held ready by the assistant, for if it can be passed into the dilated loop to deflate it, reduction of the volvulus is much simpler. It is often difficult to recognise the direction of the twist in a volvulus of pelvic colon which has undergone several turns, and it is useful to remember that the spiral is usually counter-clockwise, and that the volvulus reduces best in a clockwise direction. Volvulus is one of the two situations (internal hernia is the other) in which it is legitimate to aspirate the distended bowel by needle if reduction is difficult, the needle being inserted at the centre of a purse-string stitch, and aspiration being performed by syringe. The treatment of irreducible or non-viable volvulus of the pelvic colon still offers great difficulty, and the mortality of volvulus of the pelvic colon is still high. The operator has the choice of exteriorising the volvulus and inserting Paul's tubes into the distended loop and into the colon immediately above the volvulus, or into the transverse colon. The mortality of immediate excision is still prohibitive.

Recurrence is relatively common after reduction of a volvulus, and no form of fixation of the pelvic colon, or of plication of its mesocolon, can be guaranteed to prevent recurrence. It is best, after the first recurrence, to reduce the volvulus and to proceed to excise the pelvic colon when the patient has recovered from the acute emergency.

Mesenteric Vascular Occlusion

The management of mesenteric vascular occlusion (thrombosis and embolism) has altered significantly since the introduction of heparin. It is often possible to make a firm diagnosis of mesenteric infarction before operation. The patient provides some evidence, usually, of a causative condition—portal thrombosis, cirrhosis of the liver, a recent operation for splenectomy, endocarditis, aortic aneurysm, patent ductus arteriosus, or severe generalised athero-sclerosis. Collapse is profound and the patient looks as if he or she had suffered a serious internal haemorrhage as well as an obstruction. Blood is passed per rectum, or, if not, the diagnostic enema is often blood-stained.

When a firm diagnosis is made on these grounds, it is usually wise to avoid operation. If the infarcted bowel is resected, there is every chance that thrombosis will spread in the mesenteric vessels after operation. If no operation is performed there is every chance of the infarcted bowel recovering a collateral circulation, provid

the patient is kept alive, and provided the bowel is kept from distending To keep the patient alive fluid must be given in considerable quantities a patient may lose one-third of his blood volume or more into the whole small intestine if that is infarcted It is nearly always safe to give 2 or 3 litres of blood by drip quite rapidly If the patient suffers from heart disease and it is thought there may be a risk of over transfusion, 500 c c of saline may be run in rapidly before transfusion, and the jugular pressure observed in the neck, to see how the heart accepts this excess of fluid If there is no rise in jugular pressure blood transfusion proceeds The patient meanwhile is fully heparinised by the intravenous injection of 100 to 125 mg of heparin immediately and at six hourly intervals during the subsequent few days Gastro-intestinal suction drainage is meanwhile established and maintained When the patient has recovered from the shock of the associated blood loss, the intravenous drip is switched from blood to saline and the standard rules for water and salt administration are followed

Our successes with this form of treatment have presented us with another problem In some of our patients renal anoxia during the period of initial shock is quite serious, and on occasion has led to fatal anuria This complication was seldom seen formerly because the patients who now suffer from it would formerly have died

Neurogenic Obstruction

Two forms of neurogenic obstruction are much more successfully treated now than formerly

Spastic Ileus Spastic ileus still comes occasionally to operation. The signs of intestinal obstruction without distension and particularly if accompanied by scaphoid abdomen and by bradycardia sometimes permit pre-operative diagnosis, and the surgeon still occasionally operates In the case of the patient who presents with severe pain, to find dilated bowel merging gradually into contracted bowel without any actual cause for obstruction or even to find a contracted, narrow pallid spastic segment which can be held horizontal in the air like a lead pencil I have observed a spastic post-operative form of ileus which seemed to be due to morphine idiosyncrasy Pethedine (demerol) in full doses is unquestionably the most valuable drug in the treatment of this form of obstruction and provided an early diagnosis is made operation is of course unnecessary and even nasal suction drainage and intravenous therapy do not usually need to be employed

Paralytic (Adynamic) Ileus Paralytic ileus has benefited more than any other form of obstruction from modern methods of suction drainage and intravenous saline therapy

The reflex or true paralytic form of ileus is seldom seen now that post-operative cathartics by mouth are not employed and now that early post-operative vomiting is treated promptly by the passage of a nasal suction tube A proper understanding is now general too of certain subsidiary causes of the adynamic ileus which follows operation Careful preparation of the patient for operation, with thorough evacuation of the bowel and with correction of hypoproteinaemia and hypochloraemia is of great value in preventing post-operative distension. In abdominal operations unnecessary exposure of the intestine is avoided manipulations are carried out with gentleness and a reasonable speed is desirable and these operative attributes

together with the careful use of the abdominal pack, reduce the incidence of post operative ileus Hollow viscera exposed to a pressure as low as atmospheric and roughly handled during operation distend with gas during operation and the distension is maintained after it sometimes proceeding to ileus A high tension of alveolar oxygen, and consequently of blood oxygen is maintained during operation; cyanosis of the patient and consequently of the intestine leads in itself to dilatation Surgeons who subscribe to these requirements of abdominal surgery are less worried than others by the incidence of post-operative distension

Once distension or vomiting occurs after operation it can be promptly treated by the passage of a gastro-intestinal tube for suction and the establishment of an intravenous drip with a profit and loss account of the fluid and salt balance each day

PARALYTIC ILEUS OF PERITONITIS The distension of peritonitis spontaneous or post-operative is treated in much the same way but a word of warning seems necessary in this respect. It is inaccurate to regard the post-operative distension of peritonitis as purely paralytic Unquestionably there is a paralytic element in it and this form of post-operative distension is like true paralysis silent on ausculta tion There is also however some mechanical element present. Any bowel after operation loses to some extent its contractility and the bowel of peritonitis, bathed in pus is slower than normal bowel to recover peristalsis The bowel in peritonitis however works at a mechanical disad antage which is not present after clean abdominal operations The bowel lying low in the pel is has its loops clotted together by tenuous adhesions of fibrin This would be too slender to cause obstruction if the bowel had a normal contractility but the weakened intestinal muscle of peritonitis cannot overcome even the slight mechanical obstruction which these filmy adhesions produce The ileus of peritonitis is thus partly paralytic and partly mechanical

In the treatment of this form of ileus cathartics are of course eschewed and no special attempt is made even by hypertonic saline or spinal anaesthesia, to flog the bowel into activity It is legitimate to persist with gastro-intestinal suction and with intravenous saline and glucose over a considerable period, and I have maintained it for a month in a patient whose peristalsis has failed to return within that time Only when peristalsis becomes audible and when flatus has been passed from the rectum is it legitimate to clamp off the suction tube for a few hours at a time to see whether vomiting or distension returns

It is commonly said that paralytic ileus is treated without operation yet some times if it is found that suction must be long-continued and if pain and bowel signs return before flatus has passed from the rectum, there is some benefit in proceeding to operation In these cases it can be assumed that some mechanical obstruction is present and the patient s convalescence can be accelerated, and his or her comfort can be relieved by active intervention There is no doubt that the general health of the patient who has been on suction and intra enous alimentation for two or three weeks suffers in a rather subtle way which can be more readily recognised and remembered than described

When, after two or three weeks or even after a shorter period of the treatment of the paralytic ileus of peritonitis by suction and intravenous alimentation it is decided to operate a small incision may be made near the umbilicus The first loop of distended small intestine to present is withdrawn from the wound and a lateral

anastomosis is performed between this loop and the transverse colon The improvement in the patient s condition which follows the operation of jejuno-transverse colostomy performed at this time and in this way is quite remarkable Bowel sounds return within an hour or two and any pain which has been present disappears and the patient feels much better though flatus may not be passed until twelve or twenty-four hours later The improvement in the patient s morale is no less than the improvement in his or her comfort I have performed this operation on many occasions now and have never found the transverse colon dilated It must therefore be assumed that the small intestine only is obstructed by pelvic adhesions and that the ileus duplex of Sampson Handley is not common

Acute Obstruction of the Colon Due to Tumour

In acute obstructions of the colon, when the lesion is localised and found to be cancer operative relief is fairly standardised For tumours of the right colon (caecum ascending colon, and right end of transverse colon) a lateral anastomosis is performed between the lower ileum and transverse colon If the tumour is considered to be removable this constitutes the first stage of a two-stage resection and the anastomosis is best performed in the anti-peristaltic direction so that at the second operation of hemicolectomy a loop of ileum does not lie in front of the field of operation If at the operation for relief of obstruction the tumour is considered to be inoperable it is legitimate to perform an iso-peristaltic ileo-transverse colostomy In addition it is wise to drain the caecum. A blind loop of caecum between ileo-caecal valve and tumour may dilate subsequently in an uncomfortable way caecostomy performed at the time of relief prevents later distension of the caecum, and allows a fistula to discharge mucus from time to time in a manner that is not very inconvenient

Tumours of the left colon are best treated by transverse colostomy whether subsequent excision is anticipated or not

Tumours of the pelvic colon and of the recto-sigmoid when they produce acute obstruction are suitably treated by transverse colostomy of a defunctioning type with a well-marked spur between the colic limbs This allows for later excision and repair of the malignant segment of bowel safely

Cancers of the rectum productive of acute obstruction may if they are at a high level which permits anterior resection be treated immediately by transverse colostomy Low growths are better managed by a pelvic colostomy which allows of later combined or perineal excision of the rectum.

If the patient s condition at the time of the emergency operation is poor and if it seems desirable to relieve the obstruction by as short an operation as possible caecostomy is legitimate It is unsatisfactory however to perform this operation like a jejunostomy merely inverting a tube into the caecum and letting the caecum return to the abdomen Such a caecostomy does not drain adequately even if there is a complete obstruction distal to it and it is preferable to withdraw the caecum and the lower part of the ascending colon and to perform a formal colostomy over a glass rod

CHAPTER 13

Benign Strictures of the Rectum

LIONEL E C NORBURY

AETIOLOGY

THERE ARE MANY and varied causative factors in the production of simple strictures of the rectum

CONGENITAL STRICTURES

Congenital strictures are usually the result of inadequate union between the proctodeal invagination and the blind-gut proper Any degree of obstruction from stenosis of the anal orifice up to complete atresia of the anal canal may be present. Imperforate anus may be associated with absence of a portion or the whole of the rectum Operations on such conditions in early life may be followed by marked stricture formation I had a case of this nature under my care A child about 6 years old had been operated upon soon after birth for imperforate anus The rectum was represented by a long tubular stricture associated with complete incontinence of faeces It was found necessary to establish a permanent colostomy

ACQUIRED STRICTURES

Acquired strictures may be classified as (1) spasmodic and (2) organic

Spasmodic Strictures

Spasmodic strictures are uncommon but undoubted cases of spasm of the sphincter muscles without any obvious causative factor have been described from time to time There is strong evidence in favour of muscular spasm being an important factor in the aetiology of rectal stricture Long-continued irritation, by exciting frequent intermittent spasm, may terminate in shortening of the circular muscular fibres Spasmodic strictures are commonly associated with fissures and any form of ulceration in the anal canal.

anastomosis is performed between this loop and the transverse colon. The improvement in the patient's condition which follows the operation of jejuno-transverse colostomy performed at this time and in this way is quite remarkable. Bowel sounds return within an hour or two and any pain which has been present disappears and the patient feels much better though flatus may not be passed until twelve or twenty-four hours later. The improvement in the patient's morale is no less than the improvement in his or her comfort. I have performed this operation on many occasions now and have never found the transverse colon dilated. It must therefore be assumed that the small intestine only is obstructed by pelvic adhesions, and that the ileus duplex of Sampson Handley is not common.

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Cancers of the rectum productive of acute obstruction may, if they are at a high level which permits anterior resection, be treated immediately by transverse colostomy. Low growths are better managed by a pelvic colostomy which allows of later combined or perineal excision of the rectum.

If the patient's condition at the time of the emergency operation is poor and if it seems desirable to relieve the obstruction by as short an operation as possible, caecostomy is legitimate. It is unsatisfactory, however, to perform this operation like a jejunostomy, merely inserting a tube into the caecum and letting the caecum return to the abdomen. Such a caecostomy does not drain adequately even if there is a complete obstruction distal to it, and it is preferable to withdraw the caecum and the lower part of the ascending colon and to perform a formal colostomy over a glass rod.

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Organic, or Fibrous, Stricture

This is due to contraction of scar tissue either in the rectal wall or perirectal tissue, the result of trauma accidental or operative or of inflammation due to ordinary septic infection or to certain specific infections, such as gonorrhoea, syphilis or lymphogranuloma inguinale Chronic inflammation is the ordinary cause of fibrous stricture The mucous membrane—submucous tissue and muscular coats—is progressively infiltrated Fibrous degeneration of the deposit is attended by diminution of the calibre of the bowel (See Fig 185)

Traumatic Stricture may follow accidental wounds of the anal canal and rectum, e g sitting on a spike or gun-shot wounds in which anal or rectal tissues are lost at the time of injury or else subsequently slough as the result of sepsis Injury from an enema nozzle has been followed by stricture formation Under this heading

Fig 185 Mrs. A C aged 4 Hard indurated stricture 3 inches above anus, excised after temporary colostomy The sphincters were conserved and the bowel united by end-to-end anastomosis. The colostomy was closed nine months later (From St. Mark's Hospital.)

must also be included strictures of the rectum following labour in which sloughing of the rectal wall occurs as a result of pressure between the child's head and the promontory of the sacrum They are usually about 2 to 2½ inches above the anus

Post-operative Stricture *The removal of internal piles by operation may be followed* by a greater or lesser degree of fibrosis and constriction of the lumen of the anal canal and rectum This is especially the case if large bare areas of submucous tissue are left after removal of the piles This is likely to happen after Whitehead's operation, and is due to giving way of part of the line of suture of the mucous membrane to the anal skin The mucous membrane retracts leaving a large bare area which undergoes cicatrisation and contraction Similar stenosis may follow any method of operation for internal piles, especially the high-stripping operation The occasional judicious passage of a well lubricated finger during convalescence will often obviate this unpleasant sequela.

The use of strong chemical solutions in th injection treatment for piles has also been responsible for sloughing of the rectal wall with subsequent stricture formation Similarly strictures have been known to follow the giving of an enema in which the fluid was too hot ulceration and fibrosis resulting In the pre-antiseptic days ulceration of the rectum commonly followed any rectal operation but this is most unusual with modern methods

Operations for fistula if associated with much sepsis may be followed by rectal stricture I had a patient who as a result of several previous operations for fistula developed a well-marked stricture necessitating a colostomy

Strictures may follow operations on the rectum such as those of recto-sigmoidectomy restorati resection and operations of the abdomino-anal type also removal of extensi e benign growths of the rectum

Fig 86 Severe ulcerati colo-proctitis, stricture of rectum and colon.

Inflamed and Sloughing Internal Piles may be followed by ulceration, fibrosis and subsequent cicatricial contraction of the anal canal and rectum

Chronic Proctitis Fibrosis and stricture of the rectum may follow almost any variety of chronic proctitis *Ulcerative Colo-proctitis* (Fig 186) for example may be followed by multiple strictures in the colon and rectum These are often of considerable length *Gonorrhoeal Proctiti* is most commonly found in women (in the ratio of 5 to 1) and is usually due to the direct extension from the near-by genital passage *Syphilis* has been cited in many text-books as a common cause of fibrous stricture of the rectum There can be no doubt however that many cases previously labelled as syphilitic ha e in reality been gonorrhoeal in origin The frequency of syphilis in patients suffering from stricture of the rectum has often been noted but there are many authorities who are still doubtful as to the part it plays in the

production of rectal stricture. It is probable that chronic ulceration and sepsis, rather than syphilis itself is responsible for the stricture The chief reason in favour of this form of rectal ulceration and stricture being determined by a local cause is its prevalence in women It rarely occurs in men The easy access of discharges from the vagina to the rectum in women is obvious While the secretions from chancres may determine the ulceration the disease is due to local and not constitutional causes otherwise it would occur as frequently in men as in women

Gonorrhoea is a far more frequent infection than syphilis and the well-known tendency to the formation of cicatricial contraction is seen in the male urethra. Again the occurrence of adhesions of the Fallopian tubes and ovaries found in these cases supports the view that gonorrhoea has existed.

Lymphogranuloma Inguinale An infection with the filterable ultramicroscopic virus which is responsible for the development of climatic bubo and lymphogranuloma inguinale is an important factor in the production of inflammatory stricture of the rectum The so-called syphilitic and gonorrhoeal stricture is frequently really due to an infection with this virus It is now considered as the main cause of a stricture of the rectum of inflammatory origin It is a venereal disease found most frequently in women. The primary infection is vaginal in origin and spreads via the lymphatics to the adjacent rectal wall Diagnosis may be established by Frei s test A rectal stricture of this nature may occur in the male and is then usually the result of sodomy

Tuberculous Stricture is rarely met with in the rectum but is more common in the colon The finding of stricture in a tuberculous patient does not however justify the conclusion that it is of tuberculous origin I had a patient, a male aged about 18 years with marked tuberculous ulceration of the rectum with stricture formation, necessitating a colostomy Strictures of this nature are very painful both to the touch and to the passage of faeces

Diverticulitis may be a causative factor in producing a rectal stricture, as a result of contraction following *perirectal inflammation* This may follow diverticulitis of the pelvic colon but rarely diverticulitis of the rectum itself A diverticulum of the rectum is an uncommon condition.

Under the heading of Perirectal Inflammation must be included all varieties of pelvic cellulitis, also perirectal fibrosis following the application of radium for uterine affections, or for carcinoma of the rectum or anal canal

Radium and X ray Therapy Proctitis is a not uncommon sequel to radium treatment for uterine carcinoma or for menorrhagia and may be followed by the formation of dense fibrous tissue both in the coats and outside the wall of the bowel I would mention a patient of mine who developed acute intestinal obstruction the result of a fibrous stricture of the rectum due to applications of radium for carcinoma of the cervix This necessitated a colostomy In due course the fibrous tissue resolved and it was found possible to close the colostomy Radium treatment for carcinoma of the rectum or anal canal may be followed by a considerable degree of fibrosis It is important to remember the possibility of both rectal and perirectal fibrosis which may occur under such conditions, otherwise a mistaken diagnosis of extension of the malignant process may be made as a result of digital examination

Dysentery is a rare cause of rectal stricture Cases have been described from time

to time and I myself have seen a case which was apparently of this nature The term dysentery is used very loosely and a number of cases of stricture associated with a blood-stained mucopurulent discharge have been erroneously labelled as of dysenteric origin

Bilharzia may produce ulceration of the rectum rarely followed by stricture formation

PATHOLOGICAL FEATURES OF FIBROUS STRICTURE OF THE RECTUM

The strictures may be single or multiple—annular cylindrical funnel-shaped or irregular They usually affect the lower 3 or 4 inches of the rectum including the anal margin, and may reach into the pelvic colon There is no ulceration of the actual lining membrane of the stricture, where the ordinary cylindrical type of epithelium has been replaced by a pavement epithelium Ulceration if present is usually above the stricture but may also be below

The stricture involves the whole circumference of the bowel and is characterized by bands of indurated and fibrotic muscle between which are pockets, from the bottom of which fistulous tracks may lead to the surface in the anal region or far away on the buttocks, or may open into the vagina or bladder Sinuses may burrow in various directions amongst the thickened tissues I would mention the case of a woman aged about 40 years under my care with a stricture of the rectum associated with a recto-vaginal fistula for whom a colostomy was performed Microscopy of the hypertrophied tissue in the neighbourhood of the stricture showed no specific causative factor

Extreme narrowing may occur at several points and will often prevent the passage of even a small bougie One characteristic feature is the presence of hard polypoid excrescences in the neighbourhood of the stricture If the stricture is low down in the anal canal, these polypoid growths may surround the anal margin a condition considered by some authorities as typical of a gonorrhoeal manifestation With a fibrous stricture of long standing, these polypoid growths may form immediately above the stricture They may develop long pedicles and project through the stricture

At the site of stricture there is chronic inflammation of the mucous and submucous layers *Above the stricture* the bowel is dilated and the mucous membrane is catarrhal or ulcerated. *Below the stricture* the bowel is often ballooned owing to paralysis of the muscular coat. If the constriction is low down the tone of the sphincters is lost, the anus becomes patulous, the mucous membrane prolapses and there is loss of control

Complications may be classified as

1 Perirectal and peri-anal suppuration with sinus and fistula formation
2 Ulceration of the mucous membrane above the stricture
3 Perforation of a distension or stercoral ulcer above the stricture
4 Chronic intestinal obstruction, sometimes ending in acute obstruction due to blocking of the stenosed bowel by faecal impaction.
5 Cancer has been described as supervening upon an inflammatory stricture

CLINICAL FEATURES

The *age incidence* is 20 to 40 years and females are affected more often than males

The *symptoms* include an increasing mucopurulent and blood-stained discharge a feeling of fullness and of something in the rectum increasing constipation and frequent and ineffectual actions of the bowel with spurious diarrhoea If the stricture involves the anal canal as is often the case then incontinence of faeces is superadded There may be wasting and toxaemia.

Too much importance should not be attached to the shape and size of faecal material passed A soft mass of faeces must take its shape from the last orifice through which it passes i e the anus An irritable and spasmodic sphincter will influence the size and shape of the motions Unless the stricture is close to the anal margin

Fig 187 Sarcoma of rectum simulating fibrous stricture

and associated with loss of tone of the sphincters and a patulous anus the shape of the excretion can have no clinical significance

As the disease progresses with spread of the inflammatory process through the coats of the rectum and into the perirectal tissues pain becomes a marked and persistent feature Also when the sensitive anal canal is encroached upon pain may be intense It is not uncommon for pain to be referred to the sacral region

TREATMENT

PREVENTIVE TREATMENT

Preventive treatment implies rigid and early attention to any form of proctitis and to the causative factor Before embarking upon a line of treatment for an

established stricture examination of the rectum under general or spinal anaesthesia is advisable The condition of the bowel at the level of the stricture shoul l be noted The stricture if possible should be dilated enough to pass a small bored sigmoidoscope Care must be taken not to split the rectal wall owing to the risk of setting up perirectal inflammation The character of the bowel above the stricture should be noted.

PALLIATIVE TREATMENT

Palliative treatment resolves itself into dilatation which may be rapid or intermittent. This must be undertaken with the utmost care since serious or fatal accidents have followed These are due to splitting of the stricture with resulting perirectal spread of infection leading to cellulitis and septicaemia or even to peritonitis if the stricture extends above the peritoneal reflection I know of one case in which the injudicious passage of a sigmoidoscope under an anaesthetic led to perforation of the thinned bowel abo e the stricture the instrument entering the peritoneal cavity The dilators used should be either soft flexible rubber bougies or graduated metal dilators

Dilatation may have to be done at several sittings Stretching of a stricture is usually a painful process necessitating the use of an anaesthetic When the stricture has been successfully dilated the patient may be given a dilator of suitable size with instructions how to pass it himself provided the stricture is close to the anal orifice. If it is above the anal canal, it is safer for the surgeon to take full responsibility

Dilatation must be continued at stated intervals for some months after the stricture has been well dilated in order to counteract any tendency to recurrence

Bougies may gi e relief but permanent cure of a fibrous stricture of the rectum by the passage of bougies alone must be very rare.

OPERATIVE TREATMENT

It is only after a long period of chronic inflammation often of several years duration, that a stricture becomes sufficiently severe to call for operative interference.

Operative treatment includes internal proctotomy external proctotomy excision of the stricture plastic operation on the stricture and colostomy The choice of method will depend on the variety of stricture and on its situation

Internal Proctotomy

Internal proctotomy is indicated for a small annular stricture situated at the anus—in the anal canal or lower part of the rectum The operation is comparable with that of internal urethrotomy The stricture is partly divided by means of a blunt ended bistoury guided by a finger in the rectum The incisions should be made in several places and in a posterior or postero-lateral direction (not anteriorly) This is followed by gradual dilatation with graduated metal dilators

A large rectal tube is passed and kept in position for two or three days The patient must continue to pass a dilator himself regularly for some weeks subsequently The results are satisfactory if the patient perseveres with treatment

External Proctotomy or Posterior Linear Proctotomy

This consists in a longitudinal division of the strictured portion of the bowel through a dorsal incision The operation is comparable with that of external urethrotomy

For a Cylindrical or Funnel shaped Stricture within 3 or 4 Inches of the Anus The details of the operation are as follows The patient is placed in the left semi-prone position If the stricture is rather highly placed it may be necessary to remove the coccyx and even a portion of the sacrum in order to obtain good access The whole thickness of the rectal wall including the strictured portion is divided by a longitudinal dorsal incision Buried interrupted catgut sutures are passed through the *superficial layers* of the gut wall The wound in the bowel is thus closed longitudinally and the skin wound closed with adequate provision for drainage In this way the cicatricial tissue which formed the stricture is left un-united A drainage tube should also be placed in the anal canal The only drawback to this operation is that a faecal fistula often results and may necessitate a plastic operation for its closure at a later date One advantage is that the sphincters are not divided

For a Long Tubular Stricture Extending from the Anal Canal Upwards Possibly Complicated by Fistula In these circumstances a complete longitudinal division of the stricture with the portion of the rectum below including the sphincter muscles and anal orifice is the method of choice In this way a triangular gap is made with its apex above and base below This operation is especially suitable for cases complicated by fistulae

The details of this operation are as follows: The patient is placed in the lithotomy position The left forefinger is placed in the rectum A curved bistoury is passed through the stricture guided by the finger Its point is turned towards the sacrum and brought out through the skin at the tip of the coccyx. All intervening tissues are divided If by chance the upper part of the stricture has escaped division the edges of the wound should be held apart with retractors and division of the stricture completed The wound is packed after haemorrhage has been controlled and a rectal tube inserted *(Haemorrhage is slight if the incision is made in the midline)*

Temporary incontinence will follow this operation but control is gradually regained as the wound heals The final result as a rule is encouraging The operation affords good drainage which is of great importance in rectal operations It must of course be followed by the regular and systematic employment of dilators for some considerable period

Excision of the Stricture (Hartmann s Operation)

The patient is placed in either the lithotomy position or left semi-prone position The preliminary steps are similar to those of a Whitehead s operation for haemorrhoids A cuff of mucous membrane is raised by dissection after which the bowel wall is divided above the sphincters The rectum is exposed through a posterior incision after removal of the coccyx and is isolated and freed to well above the upper limits of the stricture *(The peritoneal cul-de-sac may have to be opened)* After mobilisation of the rectum and if necessary *the lower pelvic colon, the* bowel is divided above the stricture the strictured portion of rectum excised and the proximal end of the divided bowel brought through the sphincters and sutured to the skin at the anal margin Free drainage of the post rectal space is established

This operation is by no means easy owing to the dense perirectal fibrosis which is always present but good results have been recorded The scope of the operation is limited on account of the difficulty in getting the parts sufficiently free from gross sepsis to render the operation safe There is often much pus discharging into the rectum and numerous fistulae discharging on to the skin surface A preliminary colostomy may be necessary in order to cleanse the bowel prior to resection Again the rectum may be exposed by a posterior incision with removal of the coccyx *excision of the strictured portion and the establishment of an end to-end anastomosis* Adequate drainage must be provided since a temporary faecal fistula may result

Plastic Operation on the Stricture

An operation devised by J P Lockhart Mummery and O V Lloyd Davies begins with exposure of the rectum by a posterior approach and removal of the coccyx After mobilisation the strictured portion is di ided longitudinally and sutured transversely as in the operation of pyloroplasty Probably a temporary colostomy as a first procedure is advisable in order to promote healing of any ulceration in the region of the stricture before proceeding to the plastic operation I have no personal experience of this operation

Colostomy

Colostomy may be of a temporary nature in order to di ert the passage of faeces and so allow the ulcerated rectal mucous membrane to heal As soon as the rectum is free from ulceration and discharge the stricture is dilated and finally the colostomy is closed In illustration I would mention the following case which was under my care

A B. man aged 67 w first seen in May 1943 with history of six months frequent urge to defaecate slight haemorrhage and some loss of weight

Examination External anal tags and internal piles were present. A tight annular constriction at the level of the prostate would not admit finger Sigmoidoscopy was not possible owing to tightness of the stricture which was situated t distance of 4 cm. from the anal orifice Discharge was profuse Much abdominal distension was present from chronic intestinal obstruction. Coil of intestine were evident. The liver was not palpable and there was no evidence of ascites. The stricture was dilated under spinal anaesthesia. A portion of the stricture was removed for microscopy which showed no evidence of malignancy No specific growth fact was discovered

August 1943

Ulceration in region of stricture.
Much purulent discharge
Left iliac colostomy performed
Course of irrigation of rectum la olostomy with potassium permanganate 1 000

December 1943

Enlarged discharging inguinal glands right and left.
Stricture dilated with Hegar dilators.

January 1944

Discharge from inguinal glands had almost ceased
Stricture tight *Proctoscopy* much less ulceration.

March 1 1944

Glands in groin had subsided.
Stricture less marked
Irrigation of rectum continued—ichthyol suppositories also given.

March 21 1944

No ulceration.

Stricture rather tight—dilated with Hegar dilators.

August 9 1944

Closure of colostomy

February 1945

Finger can be passed easily through strictured area.

December 1946

No rectal symptoms.

A Permanent Colostomy may be necessary This is advisable in the case of a long, tight stricture with much perirectal infiltration and loss of sphincteric control A patient is much more comfortable with a colostomy working satisfactorily than with constant rectal discharge and incontinence of faeces let alone the danger of severe ulceration and perforation

CHAPTER 14

Cysts of the Epididymis (Spermatocele

SIR CECIL WAKELEY

CYSTS OF THE epididymis may be multiple or single and may or
contain spermatozoa. When one considers the intricate development of t
in man it is rather surprising that the condition is not more common In t
human embryo the genital gland lies in the abdomen, medial to the mes
system, and the long axes of both are vertical On reaching the false pelv
commencement of the third month their long axes are oblique or even ho
In the adult the testes lie in front, the vas deferens and spermatic vessels are
while the digital fossa, which corresponds to the hollow between the tuba
tery and the genital gland, is on the outer side (Fig 188) Up to the seventh
intra-uterine life the genital gland does not possess any differentiating fea

The testes at birth are some 13 mm long and 9 mm from side to s
grow slowly during childhood but increase rapidly in size at the onset of
At this period they measure some 40 mm long and 25 mm from side t

The youngest patient from whom I have removed a cyst of the epidid
14 years of age and the swelling had been present for four years and was
increasing in size The swelling was translucent and situated in front of the
Excision of the cyst was performed (Fig 189) through an incision in the
The cyst proved to be a small unilocular spermatocele with an upward prol
It contained milky fluid in which were numerous spermatozoa.

The oldest patient was a man of 76 years who came under observatio
swelling the size of a cricket ball in the right side of his scrotum The
appeared rapidly and the patient stated that he had only noticed it for tw
there was no history of trauma and he had not lost weight. On examin
right testicle was swollen to about three times the size of the left A tr
swelling could be detected above the enlarged testicle The cord was not t
The testicle was hard and heavy and a diagnosis of malignant disease of th
was made and orchidectomy advised Operation was performed through

incision and recovery was quick and uneventful The specimen measured $2\frac{1}{4}$ by 3 inches with $3\frac{1}{2}$ inches of the spermatic cord On section (Fig 190) the enlargement was found to be due to an oval cyst $2\frac{1}{4}$ by 2 inches and the compressed testicle occupied the posterior wall The lining of the cyst was smooth and contained thick mucoid material. Two small cysts were present in the upper pole of the epididymis Microscopically the wall of the large cyst was formed of dense fibrous tissue No trace of an epithelial lining remained but the small cysts were lined with columnar

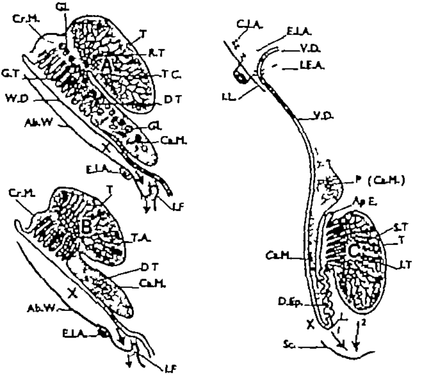

Fig 88 Diagram indicating the position of the testis and mesonephric structures during their descent from the false pelvis into the scrotum. *A* 5th to 6th week; *B* middle of 3rd month *C*, final stage

Ab.W Abdominal wall *Ap E.* appendix epididymis; *C.I.A.*, deep circumflex iliac artery *Ca.M* caudal part of mesonephros (degenerates); *Cr M.*, cranial part of mesonephros (degenerates) *D.Ep* coiled duct of epididymis *E.I.A* external iliac artery; *Gl* glomeruli; *G T* genital tubules of mesonephros *I.E.A* inferior epigastric artery *I.F* inguinal fold *I L.*, inguinal ligament; *J T* junctional tubules; *L.* loop formed by traction of gubernaculum testis *M* mesonephros *P* paradidymis *R T* rete testis; *Sc* floor of scrotum *S.T* seminiferous tubules; *T.*, testis; *T A* tunica albuginea *V D* vas deferens; *W D* Wolffian duct.

epithelium The testicle was somewhat fibrotic, but there was well marked spermatogenesis The epididymis was also fibrotic and showed dense inflammatory epididymitis involving a pre-existing spermatocele

AETIOLOGY

The aetiology of cysts of the epididymis has led to much speculation in the past There can be little doubt that by far the greater majority arise in that bridge of tissue between the testicle and epididymis namely the vasa efferentia

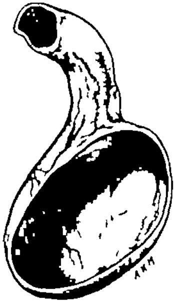

Fig 189 Small unilocular spermatocele with an upward prolongation. Removed from the right side of boy aged 14 years.

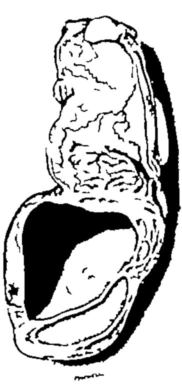

Fig 190 Specimen of large spermatocele removed from patient aged 76

Two factors alone seem to play any real part in the aetiology of these cysts, namely *trauma* and *infection* Both these agents are hard to assess because it must be admitted that most men during their lifetime suffer from some sort of trauma to their testicles It is quite conceivable that slight local trauma may rupture some of the fine seminiferous tubules and so initiate a cyst. Venereal disease in my experience cannot be said to be a factor but non-venereal infection of the epididymis is quite often a cause, and the commonest causative organism is the *Bacillus coli*

From the purely anatomical point of view cysts of the epididymis may be *extravaginal* or *intravaginal* The former are more frequent and usually arise behind the testicle between it and the epididymis and develop outside the tunica vaginalis.

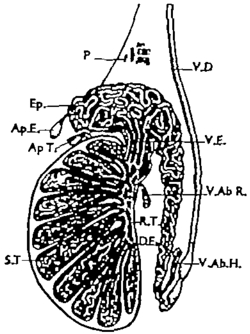

Fig 9 Diagram of adult testicle to show relation of vestigial remnants. *Ap.E.* Appendix epididymis *Ap.T.* appendix testis *D.E.* duct of epididymis; *Ep.* head of epididymis *P.*, paradidymis *R.T.* rete testis *S.T.* seminiferous tubules *V.Ab.H.*, vas aberrans of Haller *V.Ab.R.*, vas aberrans of rete testis *V.D.* vas deferens *V.E.*, vasa efferentia.

Such extra vaginal cysts displace the testicle downwards and forwards and as a rule they are single

The intra vaginal cysts occur within the tunica vaginalis. Such cysts may develop to the size of a chestnut and being situated just above the testicle lead to the false *impression on the part of the patient* that he has a third testicle Should such an intravaginal cyst burst into the tunica vaginalis a hydrocele will form, and possibly this process may be one cause of hydrocele formation.

All cysts of the epididymis are probably due either to dilat- [illegible] or more of the vasa efferentia testis (Fig 191) hence the cyst may b[illegible] bilocular or trilocular (Figs 92 93 and [illegible]) or are caused by [illegible] of some of the foetal relics always found [illegible] head of the epidi[illegible] y those

known as the organ of Giraldes (Fig 191) The *organ of Giraldes* or paradidymis is placed above the head of the epididymis in front of the veins of the pampiniform plexus of the cord and under cover of the funicular part of the tunica vaginalis This organ consists of a number of small yellowish white flattened bodies which are convoluted tubules lined with ciliated epithelium and contain a clear fluid They are attached by areolar tissue to the neighbouring structures

The *appendix testis* which is a fimbriated or sessile appendage is attached either to the head of the epididymis or to the antero-superior pole of the testis or in the angle between the two It consists of an appendage of yellowish colour and smooth

Fig 192 Large spermatocele removed from the right side of man aged 43 who had noticed the swelling for five years.

surface and is composed of connective tissue blood vessels and a convoluted canal which may end in a cul-de-sac or be in communication with the canal of the epididymis In this latter case it contains a fluid in which spermatozoa may be present

The *appendix epididymis* (vesicular or stalked appendage) which is the vestige of the cranial end of the mesonephros consists of a small vesicle measuring about 2 mm in length attached to the head of the epididymis by a pedicle (Fig 191) This pedicle is solid but the vesicle contains a colourless liquid

Both these appendages may give rise to small pedunculated cysts containing clear serum but rarely spermatozoa Such cysts are simple retention cysts and rarely give

rise to clinical signs or symptoms However they are quite common if looked for in autopsy specimens

CLINICAL MANIFESTATIONS

The common type of *spermatocele* is a retention cyst of the epididymis and is found at the upper pole of the epididymis It is usually single and varies in size from a cherry to an orange Usually there is an oval elastic translucent swelling resembling an inverted pear situated immediately above the testicle Sometimes a groove can be made out separating the swelling from the testicle From the developmental stand

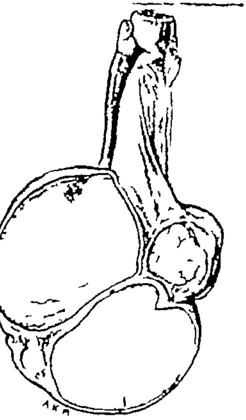

Fig 93 Bilocular spermatocele removed from the right side of man aged 55

point, multilocular and bilocular spermatoceles should be more common than they are No doubt small spermatoceles never come under clinical observation as they give rise to no symptoms and are often missed by pathologists in complete post mortem examinations

The actual swelling is cystic translucent and is often thought by the patient to be a third testicle owing to its position Translucency is always present but it varies in degree in different cases The fluid may be almost clear in some while it is opalescent in others It resembles barley water and contains spermatozoa. In my opinion the degree of opalescence has nothing to do with the number of spermatozoa which are found in the fluid a very opalescent fluid may contain few As a rule the

specific gravity of the fluid is lower than that of ordinary hydrocele fluid and there is little albumin. If the fluid is allowed to stand, two definite layers separate out, a clear one above and a whitish one below. On microscopical examination of the whitish sediment many lymphocytes are seen, together with fat globules, epithelial cells and spermatozoa. The spermatozoa will be active if the cyst is in communication with the seminiferous tubules, but dead if no such communication exists.

The cysts are above and behind the body of the testicle and are usually unilateral, most frequently on the right side, but occasionally they may be bilateral.

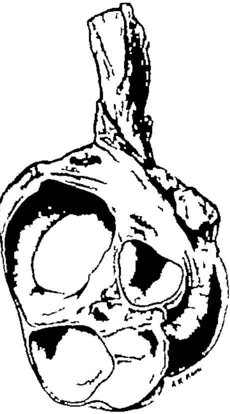

Fig. 94. Specimen of trilocular spermatocele removed from the left side of a man aged 42

TREATMENT

Excision of the cyst is the only complete cure. There can be no doubt whatever that the correct treatment of a cyst of the epididymis which is large enough to cause symptoms is complete excision. *Tapping the cyst* is hardly ever justified, as the operation has to be frequently repeated and a haematoma may result from trauma of a vessel in the cyst wall.

Injections of sclerosing fluids may prove successful in a few cases, but on the other hand they may convert a simple unilocular cyst into a very adherent multilocular one.

There is also the psychological aspect of these cysts to be considered: patients are inclined to be more worried about a swelling in the region of their genitalia than one elsewhere in the body, and a complete excision of the sac will often put an end to months of anxiety and mental strain.

Technique of Cyst Excision

These cysts should be excised through an incision in the upper part of the scrotum In *my opinion, there is no reason to make an incision over the inguinal* region and force the testicle up and out of the scrotum To say that incisions in the scrotum heal badly is just sheer ignorance and lack of clinical knowledge and operative procedure. I have observed the development of three inguinal herniae following the removal of large spermatoceles through the inguinal region.

Direct access is an important axiom in surgery and the skin of the scrotum can be sterilized perfectly well prior to operation and heals by primary union I always operate on hydroceles through the scrotal integument, and see no valid reason why

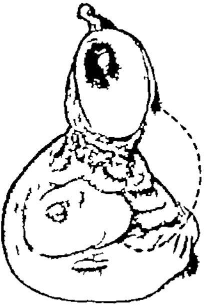

Fig 95 Specimen of trilocular spermatocele removed from the right side of man aged 47 The dotted line indicates the position of the testicle

this direct form of approach should be condemned and an indirect approach through an inguinal incision used.

When the cyst is exposed it should be carefully excised from the upper part of the epididymis Complete excision is practically always possible and should be attempted as incomplete excision leads to a recurrence (Fig 195)

In those cases in which the cyst is punctured and doubt exists as to whether complete excision has been performed, the area of attachment to the epididymis should be cauterised with the diathermy point It is most essential that haemostasis should be complete otherwise a haematoma will occur in the loose lax scrotal integument Therefore it is necessary that provision should be made for drainage by a piece of corrugated rubber tubing A suspensory bandage should be worn for some months after operation

CHAPTER 15

Carcinoma of the Head of the Pancreas

C F W ILLINGWORTH

UNDER THE HEADING Carcinoma of the Head of the Pancreas, we include not only growths arising from the acinar tissue of the head of the pancreas but also those which originate in the ampulla of Vater the duodenal papilla, and the terminal portions of the bile and pancreatic ducts To this latter group the term peri ampullary carcinoma may be applied.

Carcinoma in this region is one of the most formidable types of malignant disease The deep retroperitoneal situation of the growth its intimate relation to the duodenum portal vein and inferior vena cava and the invariable implication of the bile and pancreatic ducts make extirpation difficult while the operation is rendered more hazardous by the dangers incident to obstructive jaundice Consequently until the last decade operative treatment was almost always of a palliative character and such few attempts as were made at resection were to be regarded as heroic or perhaps foolhardy exploits justifiable only by the relentless nature of the disease

During recent years however developments in the science of surgery and in operative technique have gone some way to render carcinoma of the pancreas more amenable to treatment The introduction of vitamin K has almost eliminated the risk of post-operative bleeding Attention to fluid balance the introduction of protein hydrolysate for parenteral administration and readier recourse to blood transfusion have done much to improve the state of the patient for operation and to reduce the operative risk. Consequently operations which formerly carried a high mortality rate can now be performed with comparatively slight risk.

HISTORICAL

Surgical attention was attracted at an early stage to carcinoma of the peri ampullary region which by virtue of its small size and localised character was recognised as a fruitful field for operative attack. Early operations were of two types In most cases a simple and localised removal of the tumour was performed after

access was gained by opening the anterior wall of the duodenum. Less commonly a wedge of pancreas was removed along with a short sleeve of the second part of the duodenum with end to-end anastomosis

One of the earliest and most brilliant of the pioneer efforts in this direction was the work of Halsted of Johns Hopkins Hospital His operation performed in 1898 was *for a small growth no larger than a pea* situated at the ampulla of Vater A wedge-shaped portion of the duodenum was excised along with the adjacent part of the pancreas and the terminal portion of the common bile duct and pancreatic duct the duodenum was then closed by a circular suture and the two ducts were implanted into the duodenum at the same level Though the immediate result was satisfactory it was inevitable that such a limited resection would prove insufficient for a permanent cure and Halsted s patient died seven months later with metastases in the liver Similar lack of success attended the many other attempts at resection performed during the succeeding thirty-five years

By contrast carcinoma of the head of the pancreas proper was at that time generally recognised to be beyond the reach of surgery and few attempts were made at radical resection. Interestingly enough, one of these unsuccessful attempts (Codi illa) performed in 1898 followed a technique closely approximating to that which is again in use at the present day

The work of Whipple and his associates holds an important place in the development of the surgery of pancreatic carcinoma, and their paper published in 1935 is *a veritable milestone in the path of progress in this specialty* In this paper they reported a new operative technique which differed from the old in three essential particulars In the first place they pointed to the advisability of a two-stage procedure the first session of which is devoted primarily to the relief of the biliary obstruction, thus minimising the risks incident to a major operation on the jaundiced patient. Secondly they recommended that no attempt should be made to join the cut end of the duodenum but that instead the two ends should be closed the continuity of the alimentary tract being re-established by gastro-jejunostomy This enabled one to perform with greater ease a much more radical operation than was previously possible The third modification was the most revolutionary Until that time one of the great risks of operation had been the development of a pancreatic fistula owing to leakage from the site of implantation of the pancreatic duct. Whipple and his colleagues recognising that the external secretion of the pancreas is not essential to life ad ised that instead of re implanting the pancreatic duct into the duodenum it should be closed by means of a ligature They showed that when this was done the acinar cells of the pancreas gradually underwent atrophy and that little interference with digestion resulted from the loss of the external secretion

Since 1935 developments in surgical science have made possible further ad ances in the surgery of the pancreas and some of Whipple s original recommendations are no longer followed Thus improvement in pre-operati e care and particularly the introduction of vitamin K have enabled us to revert without added risk to the single stage procedure which offers many practical advantages while technical improvements have allowed us to revert to the *former method of implanting* the pancreatic duct and thus conserving the external secretion Operati e procedures on these lines have been described by Whipple Brunschwig, and others in America and by Pannett in England

PATHOLOGY

Carcinoma may develop in any part of the pancreas The head of the gland being the largest part is the site most often affected and it is generally accepted that from 60 to 70 per cent of growths originate in this situation.

In general the growth is characterised by extensive local spread while metastases make their appearance relatively late and are usually restricted to the local lymph glands and the liver There are exceptions to this rule however occasionally metastasis formation occurs early while in rare cases a secondary node at a considerable distance from the primary growth may provide the first clue to the nature of the disease

In its rate of progress also carcinoma of the pancreas is somewhat variable In the great majority of cases death supervenes within a few months of the first appearance of the disease but at the other extreme a few cases have been reported in which the fatal issue has been delayed for as long as four years

The primary growth may arise in any part of the head of the gland or in the uncinate process It is usually of predominantly scirrhous character It spreads at first within the gland involving the main pancreatic duct and the common bile duct Later it may invade the duodenal wall and even erupt on its mucous surface With increase in size the growth spreads to tissues around the pancreas, particularly along the gastro-duodenal artery and into the lesser omentum Commonly at this time metastases develop in lymph glands in the subpyloric group or along the common bile duct, while metastases in the liver are frequently found at an early stage

The main pathological effects of the growth are due to pressure upon adjoining structures The pancreatic duct is compressed at an early stage and in some cases obstruction to the outflow of pancreatic juice leads to characteristic changes in the stools Often, however these changes do not occur since the external secretion may be carried by anastomosing channels to the accessory duct of Santorini

The common bile duct may be involved early in the course of the disease or at a later stage depending upon the precise site of origin of the growth Consequently jaundice may occur early and indeed may constitute the initial sign or it may develop only later in the course of the disease Complete obstruction to the bile flow results only when the duct has become narrowed to an extreme degree and consequently by the time the patient reaches operation it is usual to find that the common duct is greatly dilated above the growth. The common duct may reach a diameter of 2 cm. The intrahepatic ducts are also dilated As the pressure rises above the secretory pressure of the liver the flow of bile ceases and later the dark bile in the ducts is replaced by the clear watery fluid known as white bile secreted by glands in the duct wall The presence of white bile is an indication of severe liver damage Distension of the gall-bladder is a feature in well over 90 per cent of cases as Courvoisier was the first to point out. In contrast with the ducts the gall bladder is filled with highly concentrated dark bile greenish through oxidation of the pigment and ropy with mucus

Microscopic examination of the liver shows that the first change is a dilatation of the smaller bile ducts Subsequently the bile canaliculi are dilated and contain precipitations of bile pigment (bile thrombi) The polygonal cells of the liver undergo pressure atrophy at this stage Eventually in long-standing cases a degree of obstructive biliary cirrhosis develops

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One of the earliest and most brilliant of the pioneer efforts in this direction was the work of Halsted of Johns Hopkins Hospital. His operation, performed in 1898, was for a small growth no larger than a pea, situated at the ampulla of Vater. A wedge-shaped portion of the duodenum was excised along with the adjacent part of the pancreas and the terminal portion of the common bile duct and pancreatic duct; the duodenum was then closed by a circular suture and the two ducts were implanted into the duodenum at the same level. Though the immediate result was satisfactory, it was inevitable that such a limited resection would prove insufficient for a permanent cure, and Halsted's patient died seven months later with metastases in the liver. Similar lack of success attended the many other attempts at resection performed during the succeeding thirty-five years.

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One of the earliest and most brilliant of the pioneer efforts in this direction was the work of Halsted of Johns Hopkins Hospital His operation performed in 1898 was for a small growth no larger than a pea situated at the ampulla of Vater A wedge-shaped portion of the duodenum was excised along with the adjacent part of the pancreas and the terminal portion of the common bile duct and pancreatic duct the duodenum was then closed by a circular suture and the two ducts were implanted into the duodenum at the same level Though the immediate result was satisfactory it was inevitable that such a limited resection would prove insufficient for a permanent cure and Halsted s patient died seven months later with metastases in the liver Similar lack of success attended the many other attempts at resection performed during the succeeding thirty-five years

By contrast carcinoma of the head of the pancreas proper was at that time generally recognised to be beyond the reach of surgery and few attempts were made at radical resection Interestingly enough one of these unsuccessful attempts (Codivilla) performed in 1898 followed a technique closely approximating to that which is again in use at the present day

The work of Whipple and his associates holds an important place in the development of the surgery of pancreatic carcinoma and their paper published in 1935 is a veritable milestone in the path of progress in this specialty In this paper they reported a new operative technique which differed from the old in three essential particulars In the first place they pointed to the advisability of a two-stage procedure the first session of which is devoted primarily to the relief of the biliary obstruction thus minimising the risks incident to a major operation on the jaundiced patient. Secondly they recommended that no attempt should be made to join the cut end of the duodenum but that instead the two ends should be closed the continuity of the alimentary tract being re-established by gastro-jejunostomy This enabled one to perform with greater ease a much more radical operation than was previously possible The third modification was the most revolutionary Until that time one of the great risks of operation had been the development of a pancreatic fistula owing to leakage from the site of implantation of the pancreatic duct Whipple and his colleagues, recognising that the external secretion of the pancreas is not essential to life advised that instead of re-implanting the pancreatic duct into the duodenum it should be closed by means of a ligature They showed that when this was done the acinar cells of the pancreas gradually underwent atrophy and that little interference with digestion resulted from the loss of the external secretion.

Since 1935 developments in surgical science have made possible further advances in the surgery of the pancreas and some of Whipple s original recommendations are no longer followed. Thus improvement in pre-operative care and particularly the introduction of vitamin K have enabled us to revert without added risk to the single stage procedure, which offers many practical advantages while technical improvements have allowed us to revert to the former method of implanting the pancreatic duct and thus conserving the external secretion. Operative procedures on these lines have been described by Whipple, Brunschwig, and others in America and by Pannett in England

PATHOLOGY

Carcinoma may develop in any part of the pancreas The head of the gland being the largest part is the site most often affected and it is generally accepted that from 60 to 70 per cent of growths originate in this situation

In general the growth is characterised by extensive local spread while metastases make their appearance relatively late and are usually restricted to the local lymph glands and the liver There are exceptions to this rule however; occasionally metastasis formation occurs early while in rare cases a secondary node at a considerable distance from the primary growth may provide the first clue to the nature of the disease

In its rate of progress, also carcinoma of the pancreas is somewhat variable In the great majority of cases death supervenes within a few months of the first appearance of the disease but at the other extreme a few cases have been reported in which the fatal issue has been delayed for as long as four years

The primary growth may arise in any part of the head of the gland or in the uncinate process It is usually of predominantly scirrhous character It spreads at first within the gland involving the main pancreatic duct and the common bile duct Later it may invade the duodenal wall and even erupt on its mucous surface With increase in size the growth spreads to tissues around the pancreas particularly along the gastro-duodenal artery and into the lesser omentum Commonly at this time metastases develop in lymph glands in the subpyloric group or along the common bile duct while metastases in the liver are frequently found at an early stage

The main pathological effects of the growth are due to pressure upon adjoining structures The pancreatic duct is compressed at an early stage and in some cases obstruction to the outflow of pancreatic juice leads to characteristic changes in the stools Often, however these changes do not occur since the external secretion may be carried by anastomosing channels to the accessory duct of Santorini

The common bile duct may be involved early in the course of the disease or at a later stage depending upon the precise site of origin of the growth Consequently jaundice may occur early and indeed may constitute the initial sign or it may develop only later in the course of the disease Complete obstruction to the bile flow results only when the duct has become narrowed to an extreme degree and consequently by the time the patient reaches operation it is usual to find that the common duct is greatly dilated above the growth The common duct may reach a diameter of 2 cm The intrahepatic ducts are also dilated As the pressure rises above the secretory pressure of the liver the flow of bile ceases and later the dark bile in the ducts is replaced by the clear watery fluid known as white bile secreted by glands in the duct wall The presence of white bile is an indication of severe liver damage Distension of the gall-bladder is a feature in well over 90 per cent of cases as Courvoisier was the first to point out. In contrast with the ducts the gall bladder is filled with highly concentrated dark bile greenish through oxidation of the pigment and ropy with mucus

Microscopic examination of the liver shows that the first change is a dilatation of the smaller bile ducts Subsequently the bile canaliculi are dilated and contain precipitations of bile pigment (bile thrombi) The polygonal cells of the liver undergo pressure atrophy at this stage Eventually in long-standing cases a degree of obstructive biliary cirrhosis develops

Peri-ampullary Carcinoma

These growths may arise from the ampulla itself from the duodenal aspect of the papilla (Fig 196) or from the terminal portion of the bile and pancreatic ducts. In general it may take one of two forms either a small pea like scirrhous growth buried in the head of the pancreas in close relation to the ampulla or an ulcer of typically malignant appearance situated in the wall of the duodenum in relation to the papilla

In general growths in this region conform in their progress and effects pretty closely to those in the head of the pancreas proper On the whole however they are less rapid in growth and spread. Moreover owing to their situation they tend

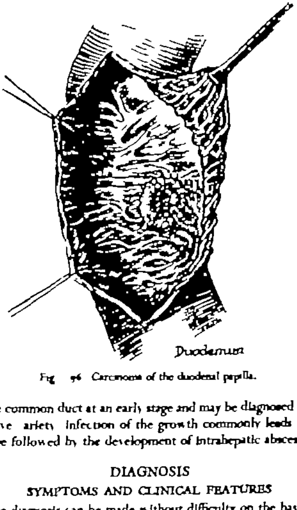

Fig 96 Carcinoma of the duodenal papilla.

to obstruct the common duct at an early stage and may be diagnosed relati ely early In the ulcerative ariety infection of the growth commonly leads to cholangeitis and this may be followed by the development of intrahepatic abscesses

DIAGNOSIS

SYMPTOMS AND CLINICAL FEATURES

Generally the diagnosis can be made without difficulty on the basis of the symptomatology and clinical examination In an elderly man the history of *jaundice* insidious in onset painless, progressi e and ultimately of a deep oli e green hue along with the finding of palpable distension of the gall bladder and such other general indications as anorexia and loss of weight, lea e little doubt as to the malignant character of the disease

Atypical features are however common and may confuse the diagnosis In such cases carcinoma of the pancreas must be distinguished from a gall-stone in the common duct from malignant obstruction secondary to growths in the stomach colon breast bronchus or elsewhere from rarer obstruction such as lymphadenomatous glands from various forms of hepatitis and finally from other diseases of the pancreas itself

It is important to recognise that carcinoma of the pancreas is not so completely painless as was formerly supposed Indeed some pain is experienced either before or after the onset of jaundice in approximately 40 per cent of cases However the pain, which is presumably due to tension within the liver capsule is generally of mild degree—a fullness or aching in the right subcostal region—and only rarely is it so severe as to lead to confusion with gall-stone colic

Variations in the depth of the jaundice also are by no means rare especially at *the start of the disease After a brief course* the jaundice may diminish or even disappear for a time only to return In such cases again the possibility of a stone in the duct may be raised This feature is most apt to occur when the growth is at the duodenal papilla and is probably due to variation in the size of the growth caused by superadded infection In some cases the resemblance to gall stone disease is heightened by the development of an ascending infection of the bile duct with symptoms of Charcot s intermittent hepatic fever

On clinical examination the most important finding is the presence of a dilated gall-bladder (*Courvoisier s sign*) Experience shows however that although the gall bladder is enlarged in well over 90 per cent of cases the distension can be recognised clinically in only half that proportion for the gall bladder may be so deeply placed or so hidden under the enlarged liver as to elude the palpating hand

Premonitory Symptoms

As in malignant disease elsewhere the secret of successful treatment is early diagnosis In the past we have been too much concerned with the one feature jaundice forgetting that this is mere evidence of a secondary complication comparable to pyloric stenosis in carcinoma of the stomach Not infrequently before the jaundice develops there are premonitory symptoms vague in character but yet sufficient to arouse the suspicions of the wary diagnostician *Pruritus* is one such symptom, which may antedate the onset of visible jaundice by several weeks or even months. Again in occasional cases *ascending infection of the bile ducts* develops at an early stage resulting in attacks of right hypochondriac discomfort with shivering and slight pyrexia recurring at intervals In all such cases estimation of the bilirubin content of the blood should be carried out in order to bring to light a latent jaundice

DIAGNOSIS AT OPERATION

Although as a rule the diagnosis of carcinoma of the pancreas at operation is abundantly obvious, surgical experience shows that opportunities for error are by no means infrequent. Thus the findings in a collective investigation reported by Fraser would appear to show that, in something like 20 per cent of cases treated by palliative operation the original diagnosis proved to be erroneous

In such circumstances (where palliative operation leads to permanent recovery) it is generally assumed that the disease has been chronic pancreatitis Doubtless in

some cases a stone in the common duct has been mistaken for carcinoma, or even the induration about a deeply placed duodenal ulcer

If the malignant nature of the disease is not obvious great care must be taken to render the diagnosis as accurate as possible This is important not only from the point of view of prognosis, but also as a guide to treatment for it is clearly only *justifiable to proceed to major resection if the diagnosis of carcinoma is well* established

In a doubtful case, before making a diagnosis, the duodenum should be thoroughly mobilised along with the head of the pancreas as described on page 351 The pancreas can then be held between fingers and thumb palpated bit by bit, and every suspicious area thoroughly appraised If this examination is carried out as a routine, errors in diagnosis can be almost eliminated If finally any element of doubt exists a biopsy may be performed a small wedge of tissue being removed from the affected part. Haemorrhage may be troublesome but with care it can be controlled by two or three fine sutures

SPECIAL INVESTIGATIONS

X ray Examination

This examination has a definite though limited value firstly to exclude opaque gall-stones and secondly to give positive evidence of the disease This evidence may be provided by examination after barium meal which may show a deformity of the duodenum caused by pressure of the distended gall-bladder while occasionally a growth at the duodenal papilla may be recognisable as a filling defect at that site The well known sign of broadening of the duodenal loop is found only at a late stage In rare cases x ray examination will show a pancreatic calculus or calcification due to previous pancreatitis

Van den Bergh Test

As a means of distinguishing between toxic and obstructive forms of jaundice, this test is now generally regarded as useless When carried out by the indirect method, however—that is to say after addition of alcohol—it provides a valuable quantitative test for the bilirubin content of the serum and if this is repeated at intervals of a few days it furnishes evidence as to the course of the disease which may be of great significance in diagnosis

Liver Function Tests

It might be expected that these tests would be of value in distinguishing obstructive jaundice from diseases such as hepatitis in which the jaundice is due primarily to liver damage At an early stage useful information may indeed, be gained especially from the hippuric acid test and the cephalin-cholesterol flocculation test, either of which will show severe impairment of function in hepatogenous jaundice and little or no impairment of function in jaundice due to malignant disease.

Unfortunately however at a later stage in the course of the disease this clear distinction is lost On the one hand in most cases of hepatitis, while the jaundice is mainly due to involvement of the polygonal cells there is in addition a partial obstruction of the bile canaliculi while, on the other hand jaundice which is primarily due to malignant obstruction is generally complicated later by secondary

damage to the polygonal cells Consequently only too often the results of liver function tests are inconclusive

Aspiration Biopsy of the Liver

Microscopic examination of fragments of liver tissue withdrawn by means of a hollow needle is of considerable value in obscure cases of jaundice particularly when the diagnosis rests between malignant obstruction and various forms of hepatitis In hepatogenous jaundice there are various degrees of degeneration of the parenchymal cells with in the later stages, fibrosis and cellular regeneration These findings contrast with the picture in obstructive jaundice which is characterised by dilatation of bile ducts and canaliculi the presence of bile thrombi and later signs of hypertrophic biliary cirrhosis Apart from distinguishing thus between the different types of jaundice aspiration biopsy may occasionally yield other evidence of value for example it may show metastatic malignant cells in the portion of tissue removed

Peritoneoscopy

In this examination a special instrument is introduced into the peritoneal cavity under local anaesthesia after preliminary distension with oxygen or air The view obtained is circumscribed but within its limitations the method may give useful information In particular the liver can be visualised readily and its surface character noted Metastases close to the liver capsule or on a neighbouring peritoneal surface may be identified Lastly the gall bladder may be inspected and its size noted. The value of this finding will be clear when it is realised that the gall bladder is distended in over 90 per cent of cases of carcinoma of the pancreas and in barely 10 per cent of other diseases

Prothrombin and Vitamin K

The risk of haemorrhage in jaundice has been known for a long time The haemorrhage usually develops a few days after operation and it takes the form of an ooze into the depths of the wound or less often from the mucous membranes As is now well known this bleeding tendency results from a deficiency of prothrombin which is due partly to faulty absorption of vitamin K from the intestines in the absence of bile and partly to faulty synthesis in the damaged liver

It is interesting to look back upon the series of research investigations in which, step by step these findings were brought to light First in 1934 there was the discovery by Dam and his co-workers in Copenhagen that a haemorrhagic state in chickens could be produced by a dietetic deficiency and that it could be cured or prevented by administering green vegetables particularly alfalfa grass Then there was the introduction by Quick of Milwaukee of a simple test for prothrombin by which it was found possible to demonstrate that the haemorrhage in jaundice as well as in the chicken disease was due to a deficiency of prothrombin Then there was the discovery that haemorrhage in jaundice could, like the chicken disease be cured by an extract of alfalfa grass Then came the identification of the effective agent as a naphthoquinone and finally the synthesis of a similar product even more effective than the naturally-occurring vitamin The whole of this series of investigations was completed within five years and formed a fascinating story of a research in

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which nutritionists physiologists chemists and clinicians all contributed a notable part.

Quick s prothrombin test consists essentially in measuring the clotting time of the blood after adding an excess of calcium and thrombokinase In such circumstances the clotting time of normal blood is short (10 to 20 seconds according to the precise conditions of the test) while if the prothrombin content is deficient the time is correspondingly lengthened

Quick s test has been advised as a test for liver function and it may be used like the other liver function tests as a diagnostic agent Its main value however is as a means of assessing the risk of haemorrhage In this connection, it must be remembered that while a low prothrombin index is significant, a normal index is not In other words if the prothrombin level is depressed there is a risk of bleeding, but if the level (pre-operative) is normal it must not be assumed that no bleeding will occur

TREATMENT

PRE-OPERATIVE CARE

Recent improvements in the radical treatment of carcinoma of the pancreas are attributable partly to technical advances in operative methods but mainly to developments in pre-operative care By judicious preparation it should now be possible to eliminate almost completely the risk of death from operative shock or haemorrhage, while the danger of liver failure can be greatly reduced

For the most part the pre-operative care follows orthodox lines To counter the risks of hepatic damage the *diet* should contain an abundance of sugar which may be taken as sucrose in orange or lemon drinks or tea or other beverages *Vitamin C* may be given also to assist wound healing If glycosuria is present *insulin* should be administered to ensure that the sugar is fully utilised. If the appetite is poor or if for any other reason sufficient sugar cannot be given by the mouth *glucose* should be given by intravenous drip If the patient is wasted an *infusion of plasma* may be given, or *protein hydrolysates* may be added to the drip

Transfusion of blood is valuable as a pre-operative measure and must, of course be carried out as a routine in cases in which the haemoglobin level is seriously depressed If transfusion is to be employed pre-operatively it should be given several days in advance of operation to enable tissues damaged by anoxia to recover completely

Apart from such general pre-operative care *vitamin K* should be given as a routine to raise the prothrombin level The dose is 1 mg intramuscularly twice daily When possible the administration should be started a week before operation and should be continued afterwards until the jaundice begins to clear

PALLIATIVE OPERATIONS

Relief of the obstructive jaundice may be obtained by anastomosing the gall bladder with the stomach, duodenum, or jejunum In any case before performing the anastomosis it is important to determine that the junction of cystic and common bile ducts has not been encroached upon by the growth This is readily ascertained when the gall-bladder is evacuated in preparation for the anastomosis for then if the dilated common duct is compressed, its clear watery white bile will escape into the gall bladder

Various considerations affect the choice of operative technique. Cholecysto-duodenostomy would seem to be the most desirable method but has the disadvantage of being technically rather difficult and is not often practised. Cholecysto-gastrostomy has been subject to criticism on the grounds that it predisposes to ascending infection of the bile passages and that in the course of time the stoma tends to undergo stenosis. Neither of these objections carries much validity in malignant disease where the expectation of life is short but they assume a greater importance where there is some doubt as to the diagnosis. In such cases cholecysto-jejunostomy should be used.

Cholecysto-Gastrostomy

In aspirating the contents of the gall bladder care should be taken to introduce the trocar fully an inch from the fundus, on the deep aspect of the viscus. The stoma which is made at the site of puncture is thus placed in the most convenient site for anastomosis.

When the gall bladder has been emptied it is opposed to the anterior surface of the stomach and an anastomosis of orthodox type is made. Finest silk sutures should be used and great care is taken to obtain a water tight closure. The opening should be as large as possible to make allowance for the tendency toward stenosis.

Cholecysto-Jejunostomy

In order to minimise the risk of ascending infection of the bile ducts, a special type of anastomosis en Y should be performed by which a segment of jejunum several inches long is interposed between the gall-bladder and the alimentary tube.

The jejunum is divided at a convenient level some 4 to 6 inches from the flexure. The distal loop is brought up in front of the transverse colon and joined to the fundus of the gall-bladder by end to-end anastomosis. The proximal loop is then implanted by end to-side anastomosis into the distal loop at a point some 8 inches lower down.

RADICAL RESECTION OF THE HEAD OF THE PANCREAS

Choice of Operation

The radical operation may be performed in one or two stages. In the latter case the first stage is designed primarily to relieve the biliary obstruction by anastomosing the gall-bladder to the jejunum. It is claimed on behalf of the two-stage procedure that it reduces the risk of liver failure and of operative shock following the major resection. On the other hand it does undoubtedly add to the difficulty in performing the resection for the operative field is partly obscured by the biliary anastomosis and access to the pancreas is consequently impaired.

There is at the present time no consensus as to the relative merits of the two procedures. With ready recourse to transfusion of plasma or blood, provided that meticulous care is taken in the performance of the operation the risk of post-operative shock is slight. In my own view the advantages of the single-stage procedure far outweigh its disadvantages and it should be practised in patients whose general condition is satisfactory provided also that the jaundice is not of long duration or severe degree.

Technique of Single-Stage Resection

The method to be described is a modification of the technique recommended by Whipple (1945) and Pannett (1946) It consists of resection of almost the whole of the duodenum along with the entire head of the pancreas followed by implantation of the common bile duct and pancreatic duct and the pyloric end of stomach severally into a loop of jejunum brought up in front of the transverse colon (Fig 1 97)

This technique has certain special advantages The use of the common bile duct for biliary anastomosis gives a direct route for the flow of bile in contrast with the tortuous route through the cystic duct and the gall-bladder and it also seems to be less liable to the risk of subsequent ascending infection of the bile passages More over both the common bile duct and the pancreatic duct are implanted into the

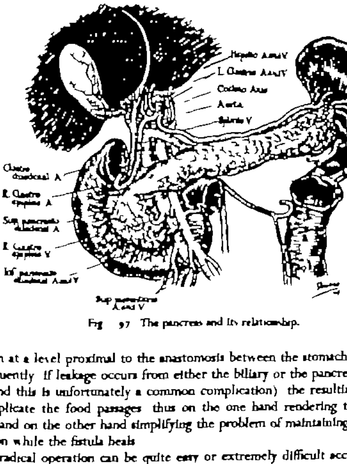

Fig 97 The pancreas and its relationship.

jejunum at a level proximal to the anastomosis between the stomach and jejunum. Consequently if leakage occurs from either the biliary or the pancreatic implantation (and this is unfortunately a common complication) the resulting fistula does not implicate the food passages thus on the one hand rendering the fistula less acti e and on the other hand simplifying the problem of maintaining the patient s nutrition while the fistula heals

The radical operation can be quite easy or extremely difficult according to the extent to which the surgeon follows the three simple rules which are indeed the keys to success in every kind of operation namely full exposure complete mobilisation and gentle respect for the li ing tissues

Incision The incision may be vertical or oblique according to preference A right paramedian incision is often satisfactory in the thin patient but if wider access is desired it can be attained b means of the oblique Kocher incision

Mobilisation of the Duodenum Next comes what is perhaps the most important step in the whole operation namely full mobilisation of the duodenum at the enclosed head of the pancreas (Fig 98) First it is necessary to divide the right hand part of the gastro-colic omentum and the peritoneal reflection which binds the hepatic flexure of the colon to the front of the pancreas When this has been done the colon can be sponged gently downwards and packed out of the operative field The peritoneum is then divided to the right side of the duodenal loop and the duodenum drawn forwards By gentle sponge dissection the whole of the duodenum from immediately beyond the pylorus to the end of its third part can then be brought forward into the wound along with the enclosed head of the pancreas

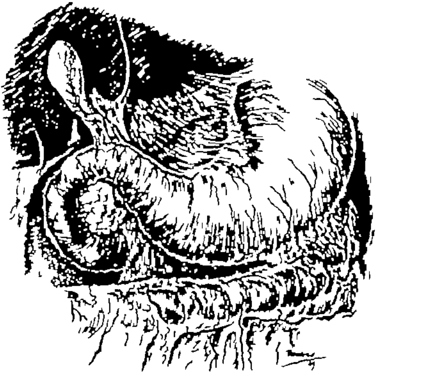

Fig 98 Resection of head of pancreas. ( ) Colon mobilised downwards Duodenum being mobilised by division of peritoneal reflection

Mobilisation of the Pylorus The next stage is the mobilisation of the pylorus much as is done in the performance of gastrectomy The right gastric and gastro-epiploic arteries and the superior pancreatico-duodenal artery with their accompanying veins are ligated and divided The dissection is now deepened in the right free margin of the lesser omentum to expose the common bile duct and the gastro-duodenal artery The bile duct which is readily identified must be dissected with care owing to the thinness of its wall and its proximity to the portal vein When it has been freed to a sufficient extent it is cut across, care being taken to see that the line of section is below the point of entry of the cystic duct. Before being cut across, the common duct may be ligated temporarily or it may be left open and the bile contained within it removed by suction The gastro-duodenal artery presents a

more difficult problem because it is not so easy to identify and moreover may be partially enveloped in the growth. It should be dissected out with care and ligated especial pains being taken to ensure that the main hepatic artery is undamaged.

Division of the Duodenum The stage is now set for division of the duodenum Proximally it is divided in its first part or more conveniently the stomach is divided just short of the pylorus The two open ends are held in clamps and protected by sterile pads Distally the duodenum is divided close to the point at which the mesenteric vessels cross The distal end of the duodenum is closed and invaginated in much the same way as is done for the duodenal stump in gastrectomy (Fig 199)

Dissection of the Superior Mesenteric Vein The most difficult step in the whole operation must now be faced namely the dissection of the superior mesenteric vein

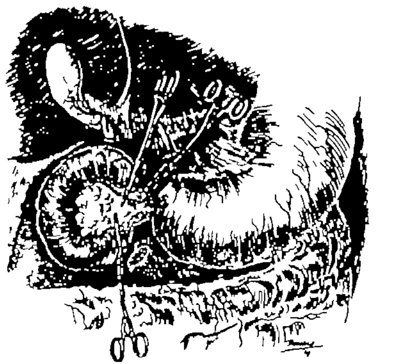

Fig 99 Resection of head of pancreas (1) Common bile duct ligated and divided. Pylorus divided between clamps. Third part of duodenum divided and distal end infolded.

as it passes behind the neck of the pancreas where it combines with the splenic vein to form the portal vein The superior mesenteric vein may lie within a groove posterior to the neck of the pancreas or may be completely surrounded by pancreatic tissue Moreover in this part of its course it receives five or six veins directly from the tissue of the pancreas (Fig 200) These veins are short very wide and thin walled and apt to cause severe haemorrhage The vein must be dissected gently out of its tunnel access being gained both from below and above and the individual venules as they are exposed must be ligated and divided When this has been done and the neck of the pancreas thus freed the resection is completed by dividing across the neck of the pancreas when the head of the pancreas and the duodenum can then be removed

Implantation of Common Bile Duct, Neck of Pancreas and Pyloric End of Stomach into Jejunum. There now lie exposed in the operative wound the cut end of the common bile duct, the neck of the pancreas with the open pancreatic duct embedded in it and the pyloric end of the stomach, temporarily occluded by a clamp. It remains to implant these structures severally into the side of a single loop of jejunum (Fig 201).

The jejunal loop chosen for this purpose, some 6 or 8 inches from its proximal end, is brought in front of the colon and laid from right to left across the operative field. The implantations are then carried out in turn from above downwards.

The common bile duct may be implanted over a tube of vitallium, but since the duct is so dilated it is often readily possible to anastomose it to the jejunum by

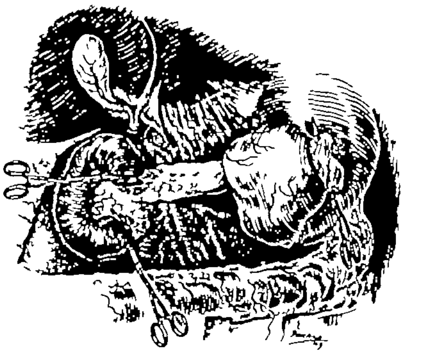

Fig 200. Resection of head of pancreas. (3) Gastro-duodenal artery divided. Superior mesenteric vein exposed.

end-to-side anastomosis of the customary type. If this is done a single row of fine silk sutures should be used, picking up the whole wall of the common duct on the one hand and the mucous membrane of the jejunum on the other hand. Interrupted silk sutures are then used to attach the outer coats of the jejunum to the connective tissues of the porta hepatis and the capsule of the liver adjoining.

The pancreatic duct is too small to allow of this technique and in most cases the best plan is to implant it over a tube. A vitallium tube is most suitable for this purpose. One end of the tube is inserted into the pancreatic duct and held there by means of a ligature. It is further secured to the neck of the pancreas by two or three interrupted catgut sutures. The other end of the tube is then implanted through a small puncture through the wall of the jejunum and held by a purse-string stitch

Further interrupted sutures are then applied to attach the jejunum securely to the neck of the pancreas

Occasionally the pancreatic duct is of such narrow calibre that it will not admit a tube. In such cases the whole thickness of the neck of the pancreas must be implanted into the jejunum (Fig 202) The procedure is technically difficult owing to the thinness of the capsule of the pancreas An incision about an inch long is made in the antimesenteric border of the jejunum and through it the neck of the pancreas is introduced into the lumen of the gut A catgut suture passed through the pancreas is inserted into the lumen of the jejunum and brought out through the jejunal wall an inch further down to act as an anchor The jejunal wall is then drawn gently

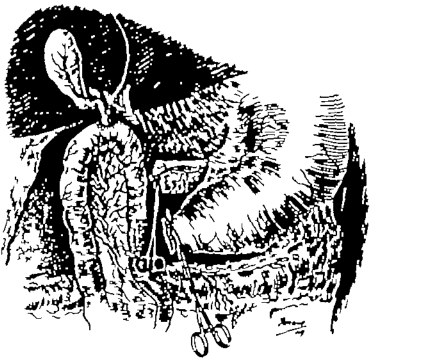

Fig 1 Resection of head of pancreas. (4) The reconstruction Common duct anastomosed to jejunum Pancreatic duct with cannula ready for implantation. Site of gastro-jejunostomy indicated.

together round the neck of the pancreas and sutured in place with fine silk stitches, meticulous care being taken to ensure a water tight seal

The final anastomosis is made between the cut pyloric end of the stomach and the jejunum a few inches further distally This anastomosis is made in the usual manner and presents no special difficulty Finally the wound is closed As a rule it is ad isable to insert a drain dow n to the icinity of the biliary and pancreatic implanta tions in case leakage occurs

Post-operative Course and Complications

The immediate post-operati e treatment is conducted along orthodox lines An intravenous drip is set up during or at the conclusion of operation and plasma or blood transfusion is gi en as necessary followed by glucose and physiological saline

sufficient to maintain the fluid balance The administration of vitamin K should be continued for several days until the risk of haemorrhage has passed

Apart from haemorrhage and liver failure the complications peculiar to this operation result from leakage from the biliary or pancreatic implantations A leakage of bile is not uncommon owing to the technical difficulty of securing a water-tight anastomosis between the common duct and the jejunal loop Fortunately however it is without serious effects and tends to close spontaneously in the course of a week or so A leakage of pancreatic juice on the other hand, has serious implications and requires detailed study

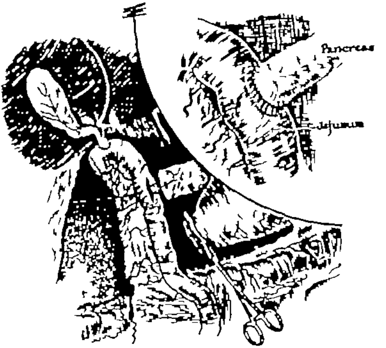

Fig 102 Resection of head of pancreas. (5) Alternative method of reconstruction

Pancreatic Fistula

This complication may be mild or severe according to the amount of pancreatic juice lost and according as its enzyme content of trypsinogen is active or inactive Commonly it is inactive at first, but later owing to coincident leakage of bile or intestinal secretion its digestive activity is enhanced

The effects of such a fistula are due on the one hand to the loss of fluid which results and on the other to digestion of the skin and the tissues bordering on the wound.

The loss of fluid, which may amount to 2 litres or more in the twenty-four hours gives rise to a severe degree of dehydration, while the particular loss of the sodium in the form of bicarbonate may give rise to a clinical state simulating Addison's disease with lethargy mental dulness anorexia and extreme fatigue Added to this constitutional upset there is the digestion of the skin which is particularly severe if the pancreatic juice is activated In severe cases the digestion of the wound may

lead to its complete disruption, while even in the milder cases the irritation and pain caused by skin digestion have a profound effect upon the general well-being of the patient.

Treatment There are three complementary lines of approach to the treatment of such a fistula

1 REPLACEMENT OF FLUID LOSS The great fluid loss must be replaced. This is done partly by copious intravenous infusions of physiological saline and protein hydrolysate and partly by the administration of adequate amounts of bicarbonate by mouth

2 REDUCTION OF THE SECRETION OF THE PANCREAS. Formerly reliance was placed principally on the use of atropine, but recent work has shown that this drug has only a transitory effect upon the pancreatic secretion Ephedrine appears to be

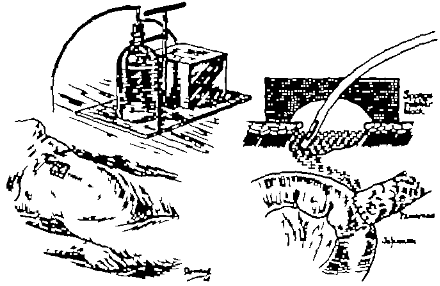

Fig 203 Post-operative pancreatic fistula. Constant suction catheter through sponge rubber block.

more valuable and when given in doses of 0·05 gm (¾ grain) it is found to cause a marked inhibition of the pancreatic juice, probably by virtue of its vasoconstrictor action

3 PROTECTION OF SKIN To protect the skin from the digestive action of the enzymes requires prompt treatment which should be initiated as soon as the fistula is recognised and before excoriation has taken place The most satisfactory method is illustrated in Fig 203 The skin alongside and around the wound is painted liberally with ordinary rubber solution A large block of sponge rubber cut to the shape indicated in the diagram is then applied so as to obtain a water tight seal Before the sponge rubber is applied it is perforated by a fine haemostat and a fine rubber catheter is drawn through the tip of the catheter being inserted a short distance into the wound alongside the drainage rubber Continuous suction is then applied so that all secretion is aspirated as it reaches the surface In this way the skin is protected from harm and the healing of the wound is but little delayed

If possible this protective device is kept in place until the fistula closes spontaneously which in favourable cases may occur in the course of a week or so

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CHAPTER 16

The Surgical Aspects of Cardiospasm

RODNEY MAINGOT

CARDIOSPASM may be defined as a condition in which there is a dilatation, hypertrophy and lengthening of the oesophagus associated with non-organic obstruction of the cardia, or to be exact, of the distal 3 to 6 cm of the oesophagus, that is the region known as the epicardia

AETIOLOGY

As the aetiology of the disease is unknown, it is not surprising that a number of synonyms, including idiopathic dilatation of the oesophagus, mega-oesophagus simple ectasia, phrenospasm and hiatal oesophagismus, have been used by various authors in describing the condition.

The title suggested by Sweet (1947) and others, namely idiopathic dilatation of the oesophagus is popular and appropriate

Einhorn (1888) gave an excellent description of cardiospasm, and suggested that the dilated oesophagus was produced by a lack of the reflex relaxation or opening of the cardia during the act of swallowing, whilst Hurst (1913) propounded the same theory and coined the term achalasia which means absence of relaxation Hurst maintained that there was not sufficient evidence to suggest the presence of actual spasm since pathological studies failed to show any hypertrophy of the muscular coats of the lower portion of the oesophagus Rake (1926) considered that the condition was due to progressive degeneration of Auerbach's plexus in the region of the epicardia. Rake's microscopical investigations were carried out on post mortem specimens of gullets of patients who had died from the ravages of the disease.

It is not unreasonable to infer that the ganglionic degeneration was in fact secondary to the inflammation and fibrosis of the oesophagus especially as many pathologists have failed to show any evidences of disease, degeneration or fibrosis of the nerve plexuses in sections taken at operation or autopsy from the epicardia in cases of cardiospasm

The term mega-oesophagus was first used by von Hacker (quoted by Finkelstein 1934) because he believed that the pathogenesis was similar to that of Hirsch sprung's disease

Knight (1934) submitted experimental evidence supporting the theory of spasm due to o eraction of the sympathetic nerve supply to the cardia The few cases upon which he performed a limited sympathectomy through an epigastric incision did not yield the results he anticipated, and this operation has in consequence been abandoned

Mitchell (1938–9) after careful anatomical studies considered that *complete* sympathetic denervation of the cardia entails a much more extensi e operation than that carried out by Knight and is quite impracticable in the human subject

We must admit that at present we do not know the cause of this interesting disease but it would appear to me from a careful study of the cases upon which I have operated that the disordered neuromuscular mechanism affecting the epicardia is a condition of spasm rather than of inco-ordination of the peristaltic wave

Cardiospasm accounts for about 20 per cent of cases of dysphagia

The condition occurs twice as commonly in females as in males and no age is exempt Whilst cardiospasm is not infrequently observed in infancy and childhood, most patients present themselves for treatment during the third or fourth decade The fact that a considerable number of cases are observed during the early years of life and that many of the sufferers from this disease give a long history of dysphagia dating back to early childhood would lend a measure of support to the congenital theory so ably upheld by Walton (1925)

In adults, however the onset often coincides with some type of psychological trauma The cardia and lower reaches of the oesophagus in these highly-strung patients appear to be controlled by their emotions and tightly contract when they are depressed, excited or angry Bockus (1943) states that a number of instances ha e been recorded in which the first symptoms followed profound shock or grief and that many patients have volunteered the information that mental agitation or nervous upsets of various sorts have preceded the onset of dysphagia

Successful ad ice and treatment by a psychiatrist or family doctor should be advocated for these early mild cases in which the underlying structural changes are so frequently shown to be minimal

In frankly established cases psychological or palliative treatment will be of no a ail and cure or amelioration of the distressing symptoms can only be achieved by the disruption of the obstructi e mechanism in the hiatal oesophagus by means of a hydrostatic bag or by a well-planned surgical attack

PATHOLOGICAL FEATURES

The characteristic pathological features are dilatation, hypertrophy and lengthen ing of the oesophagus At operation the following features are observed in every case *the cardiac orifice itself is normal in appearance and n diameter* while immediately above the cardia the terminal 3 to 6 cm of the oesophagus are pale thin atrophic and narrowed often having a diameter of not more than 1 to 1 5 cm There are no signs of adhesions and there are no evidences of inflammation past or present or of extrinsic constricting agents in the region of the hiatus cardia, or lower end of the oesophagus There is no compression of the epicardia by the adjacent liver The

ring of blood vessels ensheathed in their fatty envelope surrounding the cardia show no variation from the normal The epicardial area itself feels soft and yielding and no signs of a diffuse or localised stricture can be made out on a searching examination.

Above this narrowed segment the thick walled bloated, funnel-shaped oesophagus can be seen disappearing upwards into the chest

The dilatation of the oesophagus varies in shape according to the stage of the disease Thus in an early case it is fusiform later on it becomes flask-shaped while the sigmoid or S-shaped varieties represent an advanced stage (Fig 204)

Fig 204. The dilation of the oesophagus varies in shape according to the stage of the disease In an early case it is fusiform later on it becomes flask-shaped, while the sigmoid or S-shaped variety represents an advanced stage

Usually the dilatation is most noticeable in the lower half but in long-standing cases it may extend as far upwards as the neck and even involve the pharynx

As the disease progresses the enormously distended oesophagus swings to the right in the chest pursuing a J or serpentine course and may by virtue of its retained semi solid decomposing contents, compress the heart the great vessels, or the trachea

A final stage is reached when the oesophagus filled to capacity with retained putrifying food, is a huge distended, flabby atonic tube occupying the major portion of the thorax and sagging acutely downwards and resting on the right cupola of the diaphragm

Peristalsis now ceases as the muscular coats are in part replaced by fibrous tissue

the myenteric ganglia degenerate and the products of a low-grade infection waterlog the entire gullet. Owing to the marked sagging which occurs the cardiac orifice now comes to lie at a higher level than the most dependent portion of the inflated sigmoid loop so that gravity is prevented from playing any part in the process of emptying

COMPLICATIONS

Certain complications may arise: oesophagitis haemorrhage from the ulcerated areas in the mucosa acute perforation the formation of diverticula in any portion of the oesophagus inhalation pneumonia pleural effusion lung abscess bronchiectasis spontaneous pneumothorax nutritional deficiency states (especially those associated with a lack of vitamin B) and arthritis which is probably due to toxic absorption.

DIAGNOSIS

The cardinal features of cardiospasm are dysphagia regurgitation and retrosternal pain

The diagnosis is made by (1) history of the case (2) physical examination of the patient (3) investigation of the blood (4) oesophagoscopy and (5) barium meal x ray examination

History of the Case; Symptoms

The disease usually pursues a leisurely but nevertheless relentless course although in many instances there are brief periods of respite in the early stages

Patients suffering from cardiospasm have been described by Wooler (1948) as being oesophagus conscious They can actually feel the gullet go into intense spasm if they become excited, and they are conscious of its relaxing on taking a hot drink. The first few mouthfuls of food may cause little discomfort but further swallowing produces a sensation that the food is sticking behind the lower portion of the sternum The dysphagia is precipitated by eating quickly by taking large quantities of roughage by drinking cold or hot fluids and by bolting food

If the patient continues to eat rapidly food gushes up into the pharynx and this may produce a fit of coughing The symptoms may of course vary from day to day but in a general way they gradually become worse as the disease inevitably progresses

An acute attack of dysphagia often coincides with an emotional upset or an acute infection

As may be expected, during a late stage in the disorder dysphagia and sternal discomfort after eating increase in severity These patients often try to combat the symptoms by eating slowly selecting their diet with utmost circumspection by straining by assuming grotesque positions in an attempt to force food into the stomach and by washing down solids with copious fluid drinks But they lose weight rapidly because the obstruction above the cardia is unrelenting

If the inferior constrictor of the pharynx is not working properly they suffer from regurgitation of food into the mouth and more especially at night when in bed Some of the foul material in the oesophagus may be inhaled, thus producing bronchitis lung abscess and other pulmonary complications which are so frequently observed in advanced cases of cardiospasm They become thin and anaemic and may eventually present a severe degree of inanition

Barium Meal X-ray Examination

A barium meal x ray examination gives a distinct picture of cardiospasm The obstruction at the lower end of the oesophagus is either complete or incomplete At an early stage there is the intermittent passage of small quantities of opaque media into the stomach (Fig 205) In the last phase there is obstruction and marked dilatation with sagging little or no barium entering the stomach. If the patient inhales octyl nitrite the spasm is temporarily eased and barium may be seen flowing freely into the stomach

Where the x ray diagnosis lies between cancer of the lower end of the oesophagus and cardiospasm *inhalations of octyl nitrite during screening are helpful* as in

Fig 205 An early case of cardiospasm.

carcinoma the structured area remains impassive following inhalations of this anti spasmodic drug, whereas in the latter disease the spasm quickly yields and barium is seen to pass into the stomach

In the terminal stages the S- or J shaped gullet is a huge elongated, distorted, patulous sac incapable of vigorous peristaltic movement although the characteristic worm-like movements of the circular coat may be seen on screening indicating that the end of the struggle is in sight

On fluoroscopy in a well marked case the lower end of the oesophagus will be seen to be narrowed, and ends in a smooth rounded symmetrical cone The tip of the oesophagus is outlined as a nipple like projection the tip pointing to the left behind the diaphragm (Figs 206 207)

Oesophagoscopy

Oesophagoscopy is the greatest aid in diagnosis and should be employed in every case of cardiospasm in order to rule out organic disease and complicating lesions such as carcinoma peptic ulcer oesophagitis, diverticulitis, and so forth In carcinoma the stricture is unyielding and haemorrhagic

Fig 106

Fig 107

Fig 106 Skiagram showing moderate degree of cardiospasm.

Fig 107 Skiagram in a case of severe cardiospasm.

TREATMENT

The treatment of cardiospasm may be outlined as follows

A Medical

1. Bland nutritious non-residue diet.
2. Skilful advice and suggestion by a psychiatrist or family physician
3. Antispasmodic drugs such as eumydrin, belladonna, amyl nitrite or octyl nitrite

B. Dilatations

1. Hurst graduated mercury-filled bougies.
2. Dilatation with gum-elastic bougies and various other dilatators during oesophagoscopy
3. Plummer hydrostatic bag
4. Negus's modification of Tucker bag

C. Operations

1. Oesophago-gastrostomy
2. Oesophago-cardioplasty
3. Oesophago-cardiomyotomy

MEDICAL TREATMENT

Medical treatment psychiatry and the use of certain antispasmodic drugs and more particularly inhalations of octyl nitrite may temporarily abolish the obstruc

tion and afford some measure of relief at least this is so during the early stages of the disease For the chronic case medical therapy will prove unavailing

DILATATIONS

The old fashioned method of dilatation with Hurst's mercury tubes or oesophageal bougies has been completely abandoned as it is most distressing to the patient and rarely leads to a permanent cure.

Today the treatment of an established case of cardiospasm is by means of rupture of the constricting circular muscular fibres of the epicardia by means of Negus's modification of Tucker's bag, or else by operation

Negus's bag when skilfully employed will cure 70 per cent of the patients and there will be some improvement in a further 20 per cent A considerable number of patients in the latter group require many courses of dilatations, and surgery is indicated for the despondent cases who are averse to repeated instrumentalisation and hospitalisation

In 10 per cent of all cases of cardiospasm it is impossible or dangerous to employ the hydrostatic bag or any other type of dilator and an operation to overcome the obstruction is clearly required.

As this article deals primarily with the surgical aspects of cardiospasm no account *will be given here of the technique of dilatation or of the various bags and special* instruments—some of which are very ingenious—now used for gradual or sudden stretching of the muscular fibres of the lower end of the oesophagus and of the cardia

INDICATIONS FOR OPERATION

The indications for operation are these

1 When owing to the great size and sagging of the flask, dilatation under direct vision is a hazardous undertaking or is not feasible

2 When the patient has failed to respond to one or more courses of treatment with the hydrostatic dilator

3 In infancy and childhood Young patients frequently fail to benefit by dilatation methods and operative treatment is strikingly successful.

4 In all those cases where the diagnosis is in doubt. Here surgical enquiry is imperative in order to rule out the possibility of cancer of the cardia or of the lower end of the oesophagus

Operations for Cardiospasm

MIKULICZ OPERATION	Transgastric digital dilatation of the cardiac sphincter and lower end of the oesophagus.
OESOPHAGO-GASTROSTOMY	Anastomosis of the oesophagus to the stomach after the Finney type of pyloroplasty for chronic duodenal ulcers
3 OESOPHAGO-CARDIOPLASTY	Longitudinal division of *all* coats of the lower end of the oesophagus and cardia, the incision being carried well up into the flask-like expansion and also into the stomach itself, followed by suture in the transverse axis, i.e. after the Heineke-Mikulicz principle for benign pyloric obstruction.
4. EXTRAMUCOUS OESOPHAGO-CARDIOMYOTOMY	Heller operation, which is based on the principle of Ramstedt operation for infantile pyloric stenosis.

COMMENTS ON THE OPERATIONS

Mikulicz Operation

Mikulicz (1904) ga e an account of four successful cases in which he had lilated the cardiac sphincter and lower 2 inches or so of the oesophagus by introducing his hand into the stomach and then inserting the fingers into the oesophagus and gradually dilating it until the sphincter became paralysed After the digital dilatation the incision in the anterior wall of the stomach was closed with a three tier suture of silk

Walton (1930) was one of the chief exponents of this operation and reported 22 cases treated by the Mikulicz method Of these 3 died, and 13 of the 19 who survived were cured

The Mikulicz procedure is open to many obvious criticisms, the main danger being rupture of the lower end of the oesophagus followed by mediastinitis or peritonitis *Also the digital dilatation fails to relieve the obstruction in over 25 per* cent of the cases thus treated. So far as I can ascertain this blind operation is rarely if ever practised to-day

Oesophago-Gastrostomy

Oesophago-gastrostomy is of two types *Heyrovsky s (1912) which is a side-to-side* anastomosis between the dilated oesophagus and the stomach or Grondahl s (1916) employing the Finney type of gastro-duodenostomy for duodenal ulcer

The Finney type of repair is more popular and has the weighty support of Ochsner and DeBakey (1940) Gray and Skinner (1941) Claggett and his colleagues at the Mayo Clinic (1948) Womack (1938) Garlock (1947) and many British surgeons

The operation is performed through a vertical epigastric incision The left lateral ligament of the liver is di ided, and the peritoneum covering the epicardia is incised transversely the oesophagus is freed circumferentially and after breaking down the weak ligaments which tether the gullet to the margins of the crura, the dilated thick walled tube is drawn boldly downwards in the abdomen The liberal freeing of the lower portion of the oesophagus from its bed in the posterior mediastinum by digital and blunt dissection the forceful pulling upon the liberated segment of the gullet into the abdominal cavity in order to straighten it out so that any S- or J-shaped kinks are obliterated, and the freeing up of the fundus are essential steps in the operation

The oesophagus then must be as straight as possible a long mobile segment must be a ailable for anastomosis with the stomach contamination of the operative field must be avoided by suction applied via a Ryle tube passed into the oesophagus before *operation and retraction of the oesophagus and of the anastomosis itself* into the chest must be prevented by a few well-placed sutures which anchor the oesophagus and the fundus to the adjacent diaphragm.

A row of closely-applied sutures is placed between the adjacent margins of the oesophagus and fundus and a U-shaped incision is made through all the coats of both viscera as depicted in Figure 208

A continuous suture of No O medium chromic catgut mounted on an eyeless needle unites the posterior margins and is continued anteriorly as a Connell loop-on-the mucosa stitch in a manner similar to that described by Finney for pyloroplasty

The anastomosis is completed by introducing an anterior row of interrupted sutures as shown in Figure 208

A few stitches attach the fundus and the oesophagus to the diaphragm so as to prevent any possibility of subsequent retraction Drainage is unnecessary

This operation has three serious drawbacks The first is regurgitation of acid gastric contents into the oesophagus and mouth when the patient is reclining and the second is the possible complication of peptic ulceration in the lowest segment

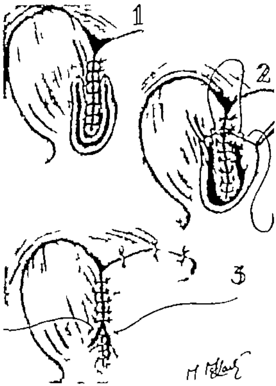

Fig 208 Oesophago-gastrostomy (After Claggett)

1 The mobilised oesophagus sutured to adjacent stomach with the horseshoe incision through all the coats of the stomach and oesophagus as in Finney s pyloroplasty

2 The posterior layer of sutures has been inserted and the anterior layer is commenced as Connell loop-on-the-mucosa stitch

3 The operation is completed by inserting a series of interrupted sutures to reinforce the anterior suture line. The fundus of the stomach is anchored to the diaphragm with a few well-placed sutures. This prevents the oesophagus from retracting into the chest.

of the oesophagus from the action of the gastric chyme on the sensitive oesophageal mucosa The third is the onset of stenosis of the stomach which may occur months or years after the operation One of my patients developed recurrent peptic ulceration close to the stoma following Grondahl s operation.

Oesophago-Cardioplasty

Oesophago-cardioplasty is the longitudinal division of all coats of the cardia and adjacent stomach and lower end of the oesophagus including at least 5 cm of the

dilated flask beyond the epicardia followed by transverse or circumferential closure with three layers of fine silk interrupted sutures (Fig 209)

As it is impossible to perform this type of operation satisfactorily through an epigastric incision the lower end of the oesophagus is approached through the bed of the left ninth rib In children an intercostal incision through the left eighth interspace gives an adequate exposure

The pleura overlying the lower part of the oesophagus is incised and the oesophagus mobilised care being taken not to injure its blood supply or the numerous branches of the vagus nerves. The cardia and the fundus of the stomach will next have to be freed A small lateral incision is made in the diaphragm to enable the

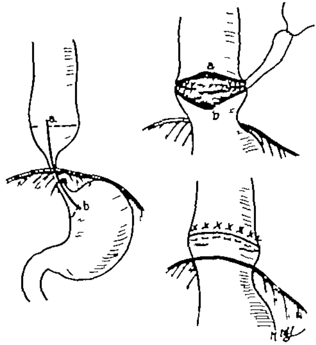

Fig 209 Oesophago-cardioplasty

uppermost portion of the stomach to be drawn into the chest and to facilitate the ligation and division of the vasa brevia close to the upper pole of the spleen.

Figure 209 shows the position of the longitudinal incision and the method of circumferential closure The final row of stitches is inserted as interrupted mattress sutures

The operation is completed by introducing a small de Pezzer catheter through a stab incision in one of the lower intercostal spaces by expanding the lung to its fullest capacity and by closing the chest wall in layers with interrupted sutures of silk

This operation is difficult to execute suturing is somewhat complicated convalescence is slow and it is often followed by minor chest complications and intercostal ache

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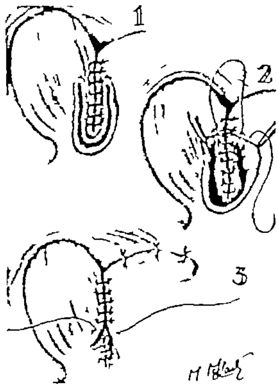

Fig Oesophago-gastrostomy (After Claggett.)

1 The mobilised oesophagus sutured to adjacent stomach with the horseshoe incision through all the coats of the stomach and oesophagus, as in Heineke pyloroplasty

2 The posterior layer of sutures has been inserted and the anterior layer is commenced as Connell loop-on-the-mucosa stitch

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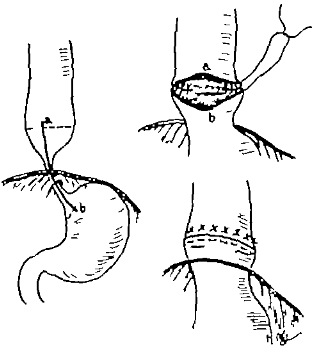

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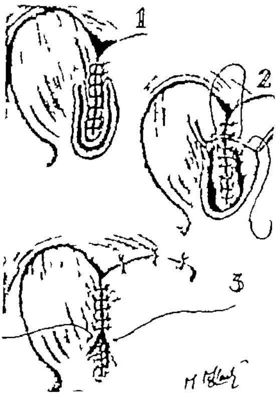

Fig 218 Oesophago-gastrostomy (After Claggett.)

1 The mobilised oesophagus sutured to adjacent stomach with the horseshoe incision through all the coats of the stomach and oesophagus, as in Finney pyloroplasty

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Pre-operative Treatment

The patient is admitted to hospital a few days before the operation is due to be performed and lavage of the oesophagus is carried out twice daily using a weak solution of sodium bicarbonate until all signs of oesophagitis have disappeared A well balanced high-calorie fluid diet rich in vitamins A B and C is prescribed but no solid food is allowed

A few hours before operation is due to commence the oesophagus is once again thoroughly irrigated with warm normal saline solution after which a Ryle or Levin tube is passed through the nostril into the stomach and the gastric contents are aspirated The indwelling tube is strapped to the nose and forehead and is allowed to remain *in situ* during the operation and also for the first one or two post-operative days

Operative Details

A high spinal anaesthetic is the one of choice

The abdomen is opened through a lengthy left epigastric paramedian incision and the empty and deflated stomach is drawn firmly downwards The left lateral hepatic ligament is put on the stretch and carefully divided as suggested by Lambert (1913) In order to permit of ready retraction of the left lobe of the liver and adequate exposure of the cardia

Three Harrington retractors (with attached lights) are inserted to give a clear view of the operative field.

The peritoneum over the oesophagus is incised transversely for 5 cm or so 2 5 cm. below the site of its reflection on to the diaphragm and by blunt and sharp dissection the oesophagus is liberated circumferentially

The left or anterior vagus nerve is drawn to the right out of harm s way (Fig 210 *a b*) When the oesophagus has been fully freed from the hiatus a sling of tape or rubber tubing is placed around the gullet and grasped with artery forceps to permit of traction downwards in the oesophagus This traction on the sling greatly aids in the mobilisation of the oesophagus which is freed by digital dissection from its bed in the posterior mediastinum and gradually pulled downwards into the peritoneal cavity for 5 to 12 cm (Figs 210 *c d*)

The oesophagus and upper end of the stomach are put on the stretch and steadied by an assistant whilst a longitudinal incision, some 10 to 15 cm in length, is made through the muscular fibres of the dilated portion of the oesophagus, the spastic zone and the cardiac region curving slightly to the left upwards towards the fundus and downwards to the mucosa. The incision is placed *anteriorly* and is made cautiously through the longitudinal muscle coat and then through the thin, somewhat adherent circular coat, dividing the fibres until the oesophageal mucosa and the gastric mucosa bulge boldly outwards without restraint (see Fig 210 *d*)

Some small blood vessels lying on the mucosa may need ligation with fine silk, but the prominent ring of vessels at the cardia needs underrunning before the longitudinal incision is made.

The muscular coats of the dilated oesophagus are extremely thick but are easily divided as they are not adherent to the submucosa The surgeon has to proceed with the utmost caution when dividing the muscular layers of the spindle like epicardia, as they are thin and the circular muscle is often firmly bound to the friable tube of

It has been warmly advocated by Sweet (1947) who presented a series of 14 consecutive highly successful cases, and in England it has been sponsored by Grey Turner and many thoracic surgeons

Extramucous Oesophago-Cardiomyotomy

Extramucous oesophago-cardiomyotomy is the operation of choice for cardiospasm as it can be performed through an epigastric incision with speed safety and precision, and the immediate and late results are excellent in every respect It is a simple procedure which can be taught to any abdominal surgeon to whom meticulous and accurate work makes a special appeal *It is associated with a negligible mortality* and a stay in hospital which does not in the average case exceed ten days There is no regurgitation of gastric contents into the oesophagus or mouth and there are no teasing sequelae such as oesophagitis or peptic ulceration A return of dysphagia or the formation of stricture has not occurred in my series of cases

In a personal series of 45 cases of cardiospasm treated by a modification of Heller s operation about to be described cure was obtained in 43 there being one death on *the third post-operative day from massive atelectasis in a feeble emaciated patient* who weighed 75 pounds was aged 75 and had suffered from dysphagia for over fifty years

TECHNIQUE OF EXTRAMUCOUS OESOPHAGO-CARDIOMYOTOMY

Heller s cardioplasty was first described in 1913 In 1921 he reported 16 cases operated upon by him without fatality and with good results in 12

The operation was first suggested by Gottstein in 1901 but Heller when he performed his series of operations made *two longitudinal incisions* an anterior and a posterior to ensure thorough division of all the constricting circular muscle fibres. *He writes*

Using an 8-cm incision, with 2 cm on the dilated portion of the oesophagus and a similar length on the fundus of the stomach I split the longitudinal muscle. This fell apart revealing the circular muscle This was similarly incised The circular muscle in the contracted area was 1–2 mm. thick, while in the dilated oesophagus it was 4 mm thick On cutting the last circular fibres the submucosa with its veins was readily recognised Following this manoeuvre the oesophagus did *not appear greatly widened in front It as accordingly repeated behind* Thereafter the contracted area was 2 fingers wide One may argue that lateral incisions are easier than dorsal and ventral The vessels, however following the greater and lesser gastric curvatures enter from the sides and anastomose round the cardia Further the agus branches are spared by my incisions

The modern operation is really based on Zaaiger s procedure (1923), as this surgeon considered that an anteriorly-placed incision through the coats of the oesophagus *epicardia, and cardia itself down to the mucous membrane* was all that was needed to produce a cure

We name certain operations after certain w ll known surgeons merely because it is customary and more convenient but it is often the best known sponsor rather than the originator of a particular operation who recei es all the praise and credit

Observations on the Operation

The operation is based on the principle of Rammstedt's pyloro-myotomy for congenital hypertrophic pyloric stenosis It differs from this procedure in that there is no gritty tumour to incise

Many observers have stated that the dilated oesophagus following this operation, although functioning normally does not contract down to its former size While this may be so for the advanced and neglected types of cardiospasm it is certainly not true for the average case as my numerous post-operative skiagrams will clearly demonstrate Therefore the more advanced the case the smaller is the subsequent contraction which obtains

Post-operative Care

In the post-operative phase no special treatment is required apart from keeping the patient on a fluid diet for the first three or four days The Ryle tube is removed on the first or second day after operation. Semi-solid nourishment is allowed on the fifth or sixth day and after that the patient is allowed light diet and is discharged about the ninth day after being tested with hearty meals

Results of Operations for Cardiospasm

(Personal Series)

OPERATION	NO OF CASES	RESULTS		
		GOOD	POOR	DEATHS
Mikulicz	3		1	2
Oesophago-gastrostomy	4	3		
Oesophago-cardioplasty		2		
Heller	45	43		
TOTALS	54	49	3	2

In this series are included 8 cases reported in *Post Graduate Medical Journal* (1944) Vol 20

CONCLUSIONS

1 Fully 70 per cent of cases of cardiospasm can be cured by treatment with Negus's modification of the Tucker's hydrostatic bag and a further 20 per cent are greatly relieved

2 Operation is called for in the remaining 10 per cent of cases and in a proportion of those who have to be subjected to repeated dilatations

3 The main indications for operation are

(a) Failure of the dilatation method

(b) The dilatation method is impracticable

mucosa. Both knife and scissors dissection are needed to liberate some fine tenacious encircling, filamentous bands above the cardia

In the average case as I have stated, the incision is fully 10 to 15 cm long, and the exposed mucosa being translucent the Ryle tube and bubbles *of gas in the* gastric fluid can be seen through the diaphanous sheet of bowel

The operation is completed by grasping the body of the stomach and squeezing it to force air and gastric juice upwards through the oesophagus to make sure that the

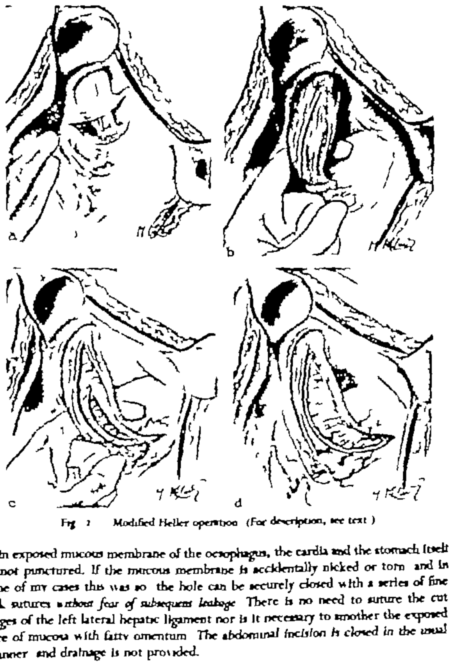

Fig 1 Modified Heller operation (For description, see text)

thin exposed mucous membrane of the oesophagus, the cardia and the stomach itself is not punctured. If the mucous membrane is accidentally nicked or torn and in nine of my cases this was so the hole can be securely closed with a series of fine silk sutures *without fear of subsequent leakage* There is no need to suture the cut edges of the left lateral hepatic ligament nor is it necessary to smother the exposed face of mucosa with fatty omentum The abdominal incision is closed in the usual manner and drainage is not provided.

Observations on the Operation

The operation is based on the principle of Ramstedt s pyloro-myotomy for congenital hypertrophic pyloric stenosis It differs from this procedure in that there is no gritty tumour to incise

Many observers have stated that the dilated oesophagus following this operation although functioning normally does not contract down to its former size While this may be so for the advanced and neglected types of cardiospasm it is certainly not true for the average case as my numerous post-operative skiagrams will clearly demonstrate Therefore the more advanced the case the smaller is the subsequent contraction which obtains

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Results of Operations for Cardiospasm

(Personal Series)

OPERATION	NO OF CASES	RESULTS		
		GOOD	POOR	DEATHS
Mikulicz	1			
Oesophago-gastrostomy	4	3		0
Oesophago-cardioplasty	2	2		
Heller	45	43		1
TOTALS	54	49	3	2

In this series are included 8 cases reported in *Post Graduate Medical Journal* (944) Vol 2

CONCLUSIONS

1 Fully 70 per cent of cases of cardiospasm can be cured by treatment with Negus s modification of the Tucker s hydrostatic bag and a further 20 per cent are greatly relieved

2 Operation is called for in the remaining 10 per cent of cases, and in a proportion of those who have to be subjected to repeated dilatations

3 The main indications for operation are

(a) Failure of the dilatation method

(b) The dilatation method is impracticable

(c) The impossibility in some cases of ruling out carcinoma and
(d) When the disease is encountered in infancy and childhood.

4. The three most popular operations for cardiospasm are
   (a) Oesophago-gastrostomy
   (b) Oesophago-cardioplasty
   (c) Oesophago-cardiomyotomy

5. The operation of choice in my opinion is Heller's extramucous oesophago-cardiomyotomy or the modification which I have here presented.

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CHAPTER 17

Surgery of Peptic Ulcer

NORMAN C TANNER

FOR MANY REASONS there has been a change in the place of surgery in the treatment of peptic ulcer of late years On the whole the change has been towards a freer use of surgery Several factors have led to this trend Improved radiological technique and the introduction of the flexible gastroscope have made diagnosis more certain. Improvements in pre-operative preparation in anaesthesia in technique in post-operative care and in chemotherapy have resulted in a world-wide lowering of operati e mortality At the same time there has been little advance in the medical treatment of ulcer and physicians are wisely changing their tactics and are exploring instead the possibilities of ulcer prevention.

In the surgical treatment of ulcer one of several operations may be decided upon. In the performance of any of these operations there are technical variations many of which may be equally satisfactory For each variant different suture materials and suture techniques are possible The development of a particular technique for a particular operation requires that the surgeon shall first master one or two techniques for each operation, and by constant thought and slight alterations here and there, an individual technique is worked out

It would be a burden to read a description of each minor variation and so the descriptions which follow are of the methods which the writer has developed as a result of reading the classical writers of studying the methods of other surgeons and discussing contemplating, and practising these operations Simplification of technique has been one goal aimed at and it is hoped that it will be helpful to other surgeons to read of methods which have been found satisfactory safe and relatively simple For the young surgeon the methods about to be described will give a basic technique on which he can build.

OPERATIONS FOR CHRONIC PEPTIC ULCER

Some measure of success and occasional triumphs have followed nearly all the operations which from time to time have been popular in the management of ulcer

With the passage of years, from careful collection and evaluation of statistics and after-histories it has become evident that many of the operations are not sufficiently successful to justify the risks of laparotomy or their results compare unfavourably with other operations of similar magnitude

Among the operations which have become rare or obsolete of late years are the following

1 Local excision of ulcer with or without gastro-jejunostomy
2 Pyloroplasty and variants such as Judd s operation
3 Gastro-duodenostomy
4. Gastro-gastrostomy
5 Wedge and sleeve resection of the stomach
6 Gastrectomy with preservation of the pyloric antrum and Devine s exclusion operation

The fact that these operations have proved inadequate or unsatisfactory as routine methods of treating peptic ulcer does not mean that they should be discarded In special circumstances one or another may prove to be a valuable procedure and thus no surgeon will find reading the classical descriptions of these operations a wasted labour

The operations which are at present most in favour in the treatment of chronic peptic ulceration are as follows

1 Partial gastrectomy with either gastro-duodenal or gastro-jejunal anastomosis
2 Gastro-jejunostomy
3 Vagotomy (see page 283)
4. Special dismantling operations for gastro-jejunal ulceration and gast o-colic fistula
5 Special operations for peptic ulcer of the oesophagus (not discussed here).

GENERAL NOTE. THE SURGICAL APPROACH

Although most British surgeons have used transverse incisions and have learnt to appreciate their ad antages, the high right or left paramedian or midline incision remains more popular The incision should not be niggardly in extent, and for gastrectomy it should reach the costal margin *In difficult high operations* removal of a large xiphisternum impro es the view

If the right paramedian incision is used and I use it nine times out of ten, the ligamentum teres will impede high gastric manipulations Therefore in the majority of cases it should be clamped and divided and ligated *high up* so that after closure of the abdomen the cut end of the ligament will lie between the liver and abdominal wall, where there will be no danger of its adhering to small intestine

In difficult duodenal cases it may help to make a right transverse extension of the incision *In dealing with high gastric ulcer it is practically never necessary to extend* the incision into the thorax unless there is also a hiatal hernia

In operating for recurrent ulcer or where previous operations on the ulcer ha e been performed it is always bett r if the old incision can be used again though it may need to be prolonged and the incision should be made straight through all layers of the abdominal wall rather than a rectus-displacing one It is to be remem-

bered that each extra incision of the skin usually means a fresh line of adhesion to the underlying peritoneum Even if a fresh incision is made it is usually necessary to free the under-surface of the old incision and so nothing is gained as a rule except a slightly easier entry to the peritoneal cavity

PARTIAL GASTRECTOMY

Except in certain circumstances to be described later partial gastrectomy is the most frequently used operation in the treatment of chronic peptic ulcer The routine techniques are described first and then the method of dealing with special difficulties will be considered

The routine operations are broadly speaking either modifications of the Polya operation or modifications of the Billroth I procedure The details of one method of performing each procedure will be given Exhaustive descriptions of the various modifications are not given because if a particular safe and satisfactory technique is known, and in this case it will be the one the author has evolved, then the young surgeon can use this as a basis on which to build his own technique

A Polya Hofmeister operation is first described The earlier part of the description is equally applicable to the Billroth I operation.

POLYA HOFMEISTER OPERATION

Surgical Exposure

This is the operation most generally applicable The peritoneal cavity is opened and a general examination of the viscera is made Finally the ulcer is examined particularly to discover its size depth of penetration, exact position the possibilities of malignancy whether there is multiple ulceration and the presence of secondary changes due to scarring Mobilisation of the stomach is commenced by making an opening through the gastro-colic omentum at a convenient place well to the left and below the gastro-epiploic arch This place is chosen because there are wide avascular areas between the epiploic vessels and the lesser sac is usually free from adhesions in this region. The opening is made below the vascular arch because it is intended to remove the arch with the stomach. The latter move has been criticised but I have done it over a thousand times without ill-effect. Two fingers of the left hand are inserted into the opening and the adjacent one or two epiploic vessels lying to the right are lifted up Cleveland s angled ligature forceps (Fig 211) are passed under the vessels, the assistant passes a ligature into them (Fig 211 *a*) which he then withdraws and ties using a triple knot The operator then clamps the epiploic vessels near the stomach and cuts between the ligature and forceps (Fig 212)

When a broad opening has been made into the lesser sac opportunity is taken to inspect the posterior wall of the ulcer The adhesions commonly present between the posterior wall of the stomach and pancreas are defined and divided. Adhesions between the stomach and the mesocolon are also freed—partly by blunt dissection, for there is no firm fibrous union as a rule It is particularly important to divide the latter adhesions because before their division the middle colic artery and the right gastro-epiploic artery often lie within a centimetre of each other Adhesions due to deep ulcer penetration should not be disturbed at this stage

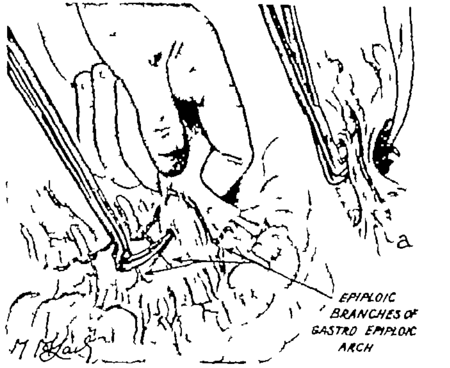


Fig. 2 1 A finger in the lesser sac displays the epiploic arch. A ligature is passed into the artery

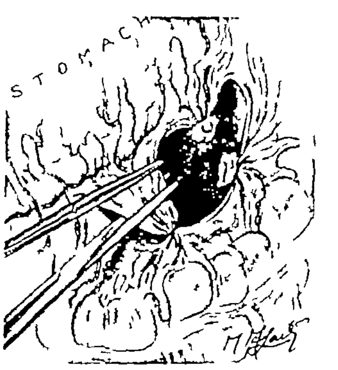


Fig. 3 2 The epiploic arches are looped near the stomach and divided.

Ligation of the epiploic vessels is continued to the right until the duodenum is reached. The right gastro-epiploic artery comes forward from a slightly posterior plane and as the duodenum is lifted forwards the artery and vein with lymph glands and fatty tissue are seen or felt in close relation to the postero-inferior part of the duodenum. A pair of dissecting forceps is gently insinuated between this vascular mass of tissue and the duodenum and the pedicle thus defined is doubly clamped, divided, and ligated. In cases of penetrating duodenal ulcer it is useful to leave artery forceps on the pedicle for this provides valuable means of traction to draw the duodenum forwards. Small vessels passing from the proximal part of the pedicle and pancreas to the duodenum are divided until the duodenum is freed for about 1 to 3 cm. beyond the pylorus, or in the cases of duodenal ulceration for 1 cm distal to the ulcer.

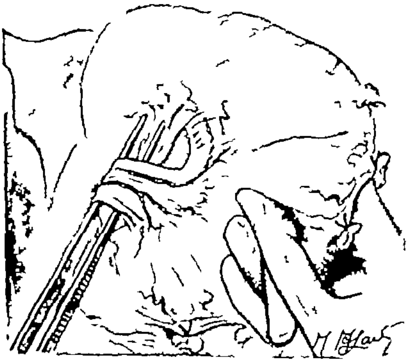


Fig. 113 Displaying the right gastric pedicle

Dissection of the Ulcer

A retractor is now placed under the right wound edge and liver. Th... is passed behind the stomach and a finger is pushed through the ... hepatic ligament above the right gastric vessels. The stomach is pull... and, with a scalpel a superficial incision is made above the duodenum ... outline. Through this incision dissecting forceps are passed (Fig ... right gastric vessels and out of the opening made in the gastro-hep... The pedicle thus isolated is carefully ligated and divided. In duoden... few more vessels running into the upper border of the duodenum ... tied and divided. In cases with much scarring and shortening of the ... is some danger in clamping near the hepatic artery or common bile

therefore fine artery forceps are used and one pair at a time is placed on the tissues *flush against the duodenal wall* With a sharp scalpel the vascular tissue is divided between duodenum and artery forceps (Fig 214) *Often it will be found that there* is no great bleeding from the duodenum, the tissue being mainly fibrous but occasionally a vessel may have to be caught on the duodenal wall Keeping thus snugly against the duodenum is I believe the main secret in the safe dissection of duodenal ulcer for even if the bile duct or hepatic artery is adherent to the duodenum such close dissection will still be safe This dissection is continued until a short length of duodenum beyond the ulcer is mobilised In gastric ulcer cases this dissection is unnecessary

Closure of the Duodenum

Two small Payr clamps are placed across the duodenum close together distal to any duodenal scar or ulcer The duodenum is divided between the clamps and the

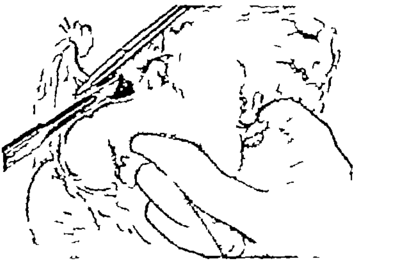


Fig 214 A single pair of artery forceps is applied close to the duodenum and the tissues divided between forceps and duodenum.

proximal clamp is covered with a swab fixed on with two Lane forceps or Maingot's special metal sheath may be used, and the stomach is pulled over to the left The duodenum in the distal clamps is surrounded with pads and the cut end is wiped with a swab soaked with proflavine 1 1000 A straight or half-circle needle threaded with fine silk is passed through the upper part of the duodenum and knotted An all-the-coats running stitch is made from upper to lower part of the crushed end of the duodenum the stitch passing loosely over the Payr clamp Better still, *artery forceps may be laid on top of the Payr clamp, the running stitch passing over* this too in order to prevent the stitches from being too tightly round the Payr clamp, thus making it impossible to open (Fig 215 *a b*) When the artery forceps are extracted, the silk will be loose enough for the Payr clamps to be opened and gently removed. In nine cases out of ten the duodenal end remains firmly sealed and it is only necessary to pull the ligature tight, loop by loop (Fig 215 *c*), and then knot it at the lower end I prefer this closure to simple ligation of the duodenum

because it is more universally applicable and the suture does not slip I also prefer it to a running mattress stitch because it is more haemostatic

A second layer is now placed on the duodenal stump and this may be either a purse-string suture which takes good bites of the seromuscular layers all round the duodenum or a running Lembert suture from the upper to the lower border of the duodenum which buries the all-the-coats layer

If the duodenum is friable or the stump to be invaginated is short, then it is wise to add a layer of interrupted silk sutures which pass from the anterior seromuscular layer of the duodenum on the right to the pancreas or the fibrous tissue adjacent to the ulcer base in the pancreas on the left (Fig 216) This turns the closed end of the duodenum into the surface of the pancreas

Finally a stitch is passed first through the anterior seromuscular layer of the duodenum then through the right gastric pedicle next through the peritoneum

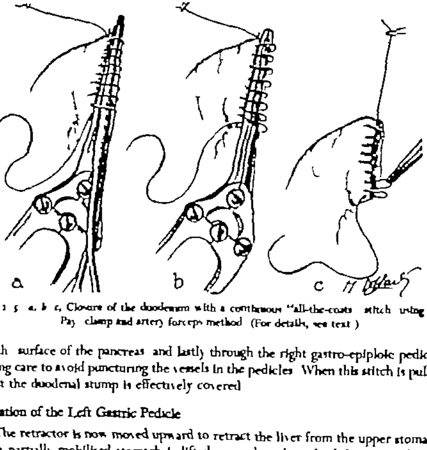


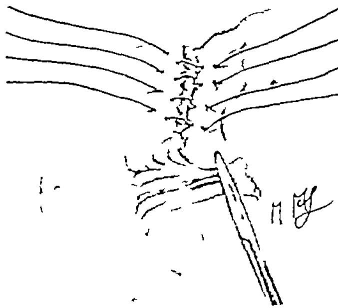
Fig 215 a, b c, Closure of the duodenum with a continuous "all-the-coats" stitch using the Pay clamp and artery forceps method (For details, see text)

on the surface of the pancreas and lastly through the right gastro-epiploic pedicle taking care to avoid puncturing the vessels in the pedicles When this stitch is pulled tight the duodenal stump is effectively covered

Ligation of the Left Gastric Pedicle

The retractor is now moved upward to retract the liver from the upper stomach. The partially mobilised stomach is lifted upwards and to the left so that the left gastric pedicle comes into view Filmy adhesions are often present, and after their division the vein artery and a few lymph glands come into view except in obese subjects or where there is much local inflammation or ulceration Arterial abnormalities are looked for In particular a hepatic branch running from the left gastric artery via the gastro-hepatic ligament to the liver If such a vessel is present it supplies part and sometimes all the systemic blood supply to the left hepatic lobe

and unless of negligible proportions it must be carefully preserved In cases of carcinoma the components of the pedicle are tied and di ided separately near the pancreas but this is unnecessary in simple ulceration because no glandular excision is required The pedicle may be conveniently ligated where the left gastric vessels di ide into ascending and descending branches (Fig 217 *a*) The posterior aspect of the lesser curve of the stomach is brought into view and with dissecting forceps, aided by palpation, the fatty tissues of the gastro-hepatic ligament with the left gastric essel and its ascending branch are separated from the lesser curve of the st mach great care being taken not to push the forceps into the muscular coat or ca ity of the stomach (Fig 217 *centre*) This point is usually 3 to 6 cm below the cardiac orifice and should be above the level of any gastric ulcer Two pairs of angled forceps are now placed on the tissues separated from the stomach—Moynihan s



Fi 6 Interrupted stitches between pancreas and antimesenteric part of the duodenum draw the sutured end of the duodenum on t the pancreas.

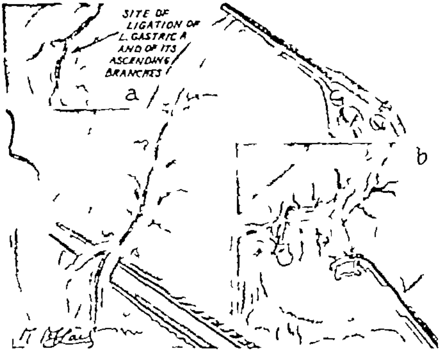
gall bladder for eps serve this purpose ery well With an aneurysm needle a stout silk ligature pa sed round the left gastric pedicle below the lowest forceps As this ligature tied the Moynihan forceps are temporarily released The pedicle is divided between the Moynihan for eps a second ligature is tied round the pedicle and the forceps on it ar removed

Next it is onfirmed that the remaining or peripheral Moynihan forceps have in their grasp all the t ssues down t th gastri wall If not, any remaining strands of tissue are divided until the muscle of the lesser urve comes into view By pulling these forceps gentl t wards the pylorus the fatty ascular and glandular tissues of the gastro-hepatic omentum trip eas l from the stomach (Fig 217 *b*) the stripping proce s being rrested onl by the branches of the left gastric artery which enter the anteri r and post rio r wall of the tomach, with a few finer branches to the middle of the lesser urv These branches are caught in fine artery forceps

divided and tied The stripping is continued until 3 to 4 cm of the lesser curve is clearly defined Its objects are (1) to demonstrate the stomach edge clearly thus making clamp application and suturing more easy and (2) to render the stripped part of the stomach more elastic so that it can be drawn to the wound surface

The division of the left gastric pedicle will have made the stomach more mobile and further vessels on the greater curvature the left gastro-epiploic and two or three vasa brevia are now firmly ligated and divided

These vessels should be tied singly as they are often surrounded by fatty tissue and are liable to slip out unless firmly secured At times it will be found that the



F 17

The point at which it is convenient to ligature and divide the left gastric vessel
Centre Displacing the left gastric pedicle
b The fatty and vascular tissue is stripped from the lesser curve of the stomach by drawing the forceps downward

spleen is adherent to the diaphragm and if so downward traction of the stomach may tear the spleen near its hilum This must be avoided in such cases by exerting only slight downward traction and performing the division of the vasa brevia deeply with the aid of a long-bladed retractor and long right-angled artery forceps In any event it is wise to inspect the splenic hilum at the end of the operation—a *minor* tear can at times be dealt with by the application of crushed muscle or cellulose alginate Rarely splenectomy is required on one occasion I had to perform splenectomy forty-eight hours after gastrectomy for a delayed rupture no doubt resulting from a subcapsular tear at the time of operation

The level of gastric transection will depend on the position of the ulcer for which

the resection is being performed. There is now considerable evidence to prove that the higher the gastrectomy the lower is the recurrent ulcer rate Even more important is the undoubted fact that recurrent ulcer after gastrectomy is most likely to occur after operations for anastomotic ulcer occasionally appears after operation for duodenal ulcer and is least common after operation for gastric ulcer Therefore for ulceration of the body of the stomach a gastrectomy which removes the ulcer is high enough though it is better in all cases to remove the lesser curve up to within 3 to 6 cm of the cardiac orifice For duodenal and anastomotic ulcer a high division of the lesser curve is made and the greater curve is divided between the level of the hilum and lower pole of the spleen which means the division of some three or four vasa brevia as a rule Of course recurrences would be less likely if only a cuff of stomach were left, but one must bear in mind that such high resections are associated with a greater risk of post-operative discomfort, malnutrition, and anaemia and it is not justifiable to make such resections in all cases for the sake of the 3 per cent in which recurrent ulceration will take place

Preparation for Anastomosis

The vessels on the greater curve adjacent to the proposed line of section are tied and divided close to the stomach wall The stomach is lifted well forwards A Lane gastro-enterostomy clamp is placed on the stomach 2 cm above the proposed line of section. It is unnecessary to have rubber sheaths on the clamp blades I have discarded them since I was handed a pair of crushing clamps neatly encased in rubber! In some deep-chested individuals it may be difficult to use clamps in which case a non-clamp method is used.

The next decision to make is whether the anastomosis is to be antecolic or retrocolic The world's surgical literature gives abundant evidence of the satisfactory results which follow either method, and so it is logical to use the method which best suits the individual case though the surgeon may also be permitted a preference for one or other method

The retrocolic method is especially easy where there is a long mesocolon and a wide avascular area to the left of the middle colic artery It is better used also in patients with adhesions between colon and parietes (although if these are widespread the Billroth I method is indicated) In the presence of short fat or closely vascularized mesocolon, the antecolic situation is more suitable

The Antecolic Operation This is the simpler of the two method A loop of jejunum is picked up at a point where the mesentery is long enough to bring it as high as the cardia Its upper end should be 15 to 25 cm. from the duodeno-jejunal junction. A segment of the loop rather longer than the diameter of the stomach is held up by the operator and the assistant lips on the second of the Lane clamps The clamp must be on bowel throughout its length and not on meso-jejunum or the haemostatic effect of the clamp will be lost The two clamps are now approximated the proximal part of the jejunal segment being placed against the lesser curve of the stomach

The Retrocolic Operation The colon is lifted upwards and the anatomy of the middle colic vessels, which varies considerably is studied. An incision is made in the avascular area which usually lies to the left of the middle colic vessels The incision should not approach the marginal artery or the base of the mesentery too closely

The edges of this incision will ultimately be sutured round the stomach and it is convenient to stitch the posterior margin at this stage Either the right or the left margin may be sutured to the posterior wall of the stomach In the former case (Fig 218 *a*) the lesser curve and in the latter (Fig 218 *b*) the greater curve will be nearer the colon The latter method is less confusing, but may be difficult to perform if the mesocolon is short and the incision is near its root because the part of the incision nearest the root of the mesentery has to be brought up to the lesser curve of the stomach

Having sutured half the mesocolic opening to the posterior wall of the stomach proximal to the clamp with three or four interrupted stitches a loop of proximal jejunum is drawn through the mesocolon and caught in the second Lane clamp

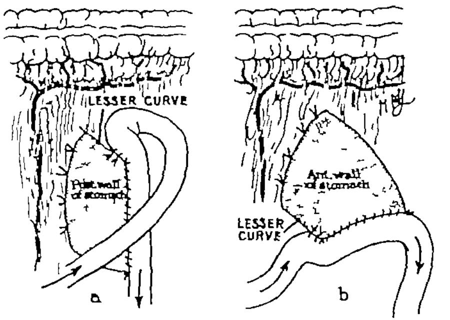


Fig 218

The right margin of the mesocolon is stitched t the posterior wall of the stomach. (The method favoured by the author)

b The right margin of the mesocolon is stitched to the anterior wall of the stomach (The method described in most textbooks.)

much as described for the antecolic operation except that in this case the loop is higher only 10 to 15 cm from the duodeno-jejunal junction The two clamps are locked as before with the proximal jejunum nearer the lesser curve of the stomach.

The Anastomosis

Theoretical Considerations The writer constructs a valved stoma of the Polya-Hofmeister type and has aimed at the greatest possible simplicity The object is to make a stoma of half the diameter of the stomach This is adequate in extent being always wider than the jejunal diameter which is the final regulator of the speed of emptying The lesser curve half of the cut end of the stomach is closed for the following reasons:

the resection is being performed There is now considerable evidence to prove that the higher the gastrectomy the lower is the recurrent ulcer rate Even more important is the undoubted fact that recurrent ulcer after gastrectomy is most likely to occur after operations for anastomotic ulcer occasionally appears after operation for duodenal ulcer and is least common after operation for gastric ulcer Therefore for ulceration of the body of the stomach a gastrectomy which removes the ulcer is high enough though it is better in all cases to remove the lesser curve up to within 3 to 6 cm of the cardiac orifice For duodenal and anastomotic ulcer a high division of the lesser curve is made and the greater curve is divided between the level of the hilum and lower pole of the spleen, which means the division of some three or four vasa brevia as a rule Of course recurrences would be less likely if only a cuff of stomach were left, but one must bear in mind that such high resections are associated with a greater risk of post-operative discomfort, malnutrition, and anaemia and it is not justifiable to make such resections in all cases for the sake of the 3 per cent in which recurrent ulceration will take place

Preparation for Anastomosis

The vessels on the greater curve adjacent to the proposed line of section are tied and divided close to the stomach wall The stomach is lifted well forwards A Lane gastro-enterostomy clamp is placed on the stomach 2 cm above the proposed line of section It is unnecessary to have rubber sheaths on the clamp blades I have discarded them since I was handed a pair of crushing clamps neatly encased in rubber! In some deep-chested individuals it may be difficult to use clamps in which case a non-clamp method is used

The next decision to make is whether the anastomosis is to be antecolic or retrocolic The world a surgical literature gives abundant evidence of the satisfactory results which follow either method, and so it is logical to use the method which best suits the individual case though the surgeon may also be permitted a preference for one or other method

The retrocolic method is especially easy where there is a long mesocolon and a wide avascular area to the left of the middle colic artery It is better used also in patients with adhesions between colon and parietes (although if these are wide spread the Billroth I method is indicated) In the presence of short, fat or closely vascularized mesocolon, the antecolic situation is more suitable

The Antecolic Operation This is the simpler of the two methods A loop of jejunum is picked up at a point where the mesentery is long enough to bring it as high as the cardia Its upper end should be 15 to 25 cm from the duodeno-jejunal junction. A segment of the loop rather longer than the diameter of the stomach is held up by the operator and the assistant slips on the second of the Lane clamps The clamp must be on bowel throughout its length and not on meso-jejunum or the haemostatic effect of the clamp will be lost The two clamps are now approximated, the proximal part of the jejunal segment being placed against the lesser curve of the stomach

The Retrocolic Operation The colon is lifted upwards and the anatomy of the middle colic vessels which varies considerably is studied. An incision is made in the avascular area which usually lies to the left of the middle colic vessels. The incision should not approach the marginal artery or the base of the mesentery too closely

The edges of this incision will ultimately be sutured round the stomach and it is convenient to stitch the posterior margin at this stage. Either the right or the left margin may be sutured to the posterior wall of the stomach. In the former case (Fig. 218 *a*) the lesser curve and in the latter (Fig. 218 *b*) the greater curve will be nearer the colon. The latter method is less confusing but may be difficult to perform if the mesocolon is short and the incision is near its root because the part of the incision nearest the root of the mesentery has to be brought up to the lesser curve of the stomach.

Having sutured half the mesocolic opening to the posterior wall of the stomach proximal to the clamp with three or four interrupted stitches, a loop of proximal jejunum is drawn through the mesocolon and caught in the second Lane clamp

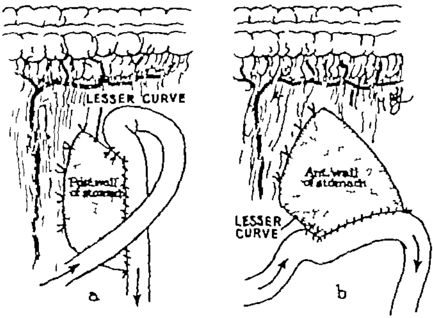


Fig. 218

a. The right margin of the mesocolon is stitched to the posterior wall of the stomach. (The method favoured by the author.)

b. The right margin of the mesocolon is stitched to the anterior wall of the stomach. (The method described in most textbooks.)

much as described for the antecolic operation, except that in this case the loop is higher, only 10 to 15 cm. from the duodeno-jejunal junction. The two clamps are locked as before, with the proximal jejunum nearer the lesser curve of the stomach.

The Anastomosis

Theoretical Considerations. The writer constructs a valved stoma of the "Polya-Hofmeister" type, and has aimed at the greatest possible simplicity. The object is to make a stoma of half the diameter of the stomach. This is adequate in extent, being always wider than the jejunal diameter, which is the final regulator of the speed of emptying. The lesser curve half of the cut end of the stomach is closed for the following reasons.

1 There is more tension at the lesser curve part of a gastro-jejunal anastomosis.
2 The lesser curve is not so well peritonealised and thus is less suitable for gastro-jejunal anastomosis
3 The greater curve is more mobile and so more suitable for attachment to the more actively functioning efferent limb
4 The lesser curve is generally higher than the greater curve after gastrectomy and thus gra ity aids emptying
5 Closure of the lesser curve side of the cut end of stomach diminishes the tendency for food to enter the proximal blind closed loop of duod num by a alvular mechanism

Suture Materials So far as the suturing material is concerned it is well to use an absorbable suture in those parts of the suture line through which food will eventually pass for the stoma usually tends to become wider than it is at the moment when suturing is finished This usually means that catgut must be used though suturing may be made with interrupted non-absorbable stitches The latter is laborious The writer has used continuous catgut suturing without leakage for between one and two thousand gastro-jejunal anastomoses and so prefers it

Haemostasis Haemostasis depends on the technique of suturing A continuous running over-and-o er suture taking all the coats and kept moderately tense and used for *both anterior and posterior* suture lines, will be haemostatic A reasonable amount of tissue must be taken with each stitch and the stitches should be about half as wide apart as they are deep The anterior all the-coats layer may be made to invert by pressure of the left thumb

Some techniques of continuous or interrupted suturing are not haemostatic for example the continuous mattress stitch (Connell) If such suture method are used, then the stomach and jejunum are opened by first dividing the seromuscular tissues down to the mucosa All isible essels are caught in fine artery forceps and tied. After this the mucosa may be opened and the anastomosis made

Closed Anastomosis Open gastro-jejunal anastomoses for ulcer keeping soiling at a minimum do not lead to infection presumably because of the antiseptic properties of the acid juice Thus the use of closed methods is rath r like battl ng with a non-existent enemy

Technique of Anastomosis

When the stomach and jejunum are secure in the Lane clamps the clamps are either swung round in the line of the patient s body or the surgeon may rotate his own body to f ce the lamps at a on enient angle Towels are placed to protect each wound edg In addition the writer has introduced a special red anti-soiling towel This is a piec of linen dyed red 36 by 30 inches, with a split extending from the middle of one end fo 12 inches with a pocket at the end of the split (Fig 2 9) This split to el is drawn up on either side of the clamps and the clamp handles fall into the pocket Unt l the open part of the anastomosis is completed, all instrument and wabs are kept on th s red tow l

Using No OO hromicised atgut on a atraumatic needle the surgeon unites the adjacent parts of th whol diameter of the stomach and the adjacent jejunum by a continuous L mbert st t h tarting at the greater curve and ending with a

lock stitch A Payr clamp is placed on the lesser curvature half of the stomach just beyond the Lembert stitches A non-crushing clamp is placed on the whole diameter of the stomach beyond the Payr clamp With a scalpel the stomach is transected cutting it flush with the Payr clamp and leaving enough of the greater curve half of the stomach beyond the Lane clamp for the subsequent anastomosis

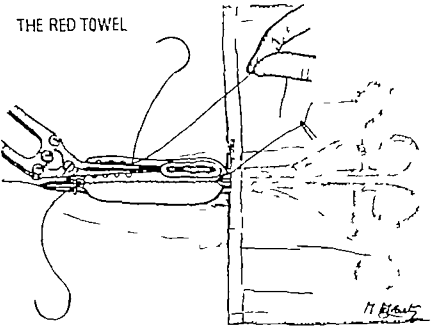


Fig 219 Tanner "anti-soiling" towel with split for the bowel and pocket for the clamp handles A "sewing-machine" stitch is placed under the Payr clamp which closes the lesser curve half of the stomach

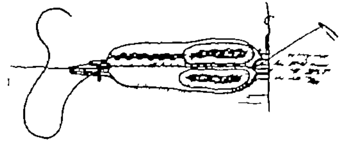
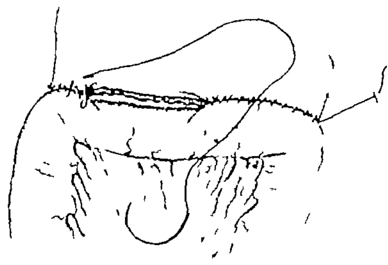


Fig 220 An opening is made in the jejunum of equal length to the opening left in the stomach.

A "sewing-machine" type of stitch is used to close the lesser curve half of the stomach (Fig 219) The Payr clamp is removed and the suture is tightened. (As this closed part does not form part of the stoma a non-absorbable suture material may be used) This leaves half the stomach diameter open, and the jejunum is opened to a corresponding extent (Fig 220) Again with fine catgut an "all-the coats" stitch is commenced at the greater curve of the stomach to unite the

posterior layers of the stomach and jejunum, and after the turn where the machine stitch ends is carefully taken the anterior layers are united. As this completes the open part of the anastomosis the Lane clamps anti-soiling towel and the

Fig 21



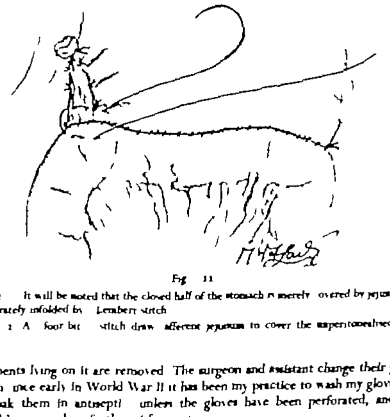


Fig 21

Fig 2 It will be noted that the closed half of the stomach is merely overed by jejunum and not separately infolded by Lembert stitch

Fig 1 2 A four bit stitch draw afferent jejunum to cover the unperitonealised lesser curve

instruments lying on it are removed The surgeon and assistant change their gloves (though once early in World War II it has been my practice to wash my gloves and then soak them in antisepti unless the gloves have been perforated, and this method has pro ed perfectly satisfactory)

The original Lembert stitch is now picked up again and continued round the lesser curve of the stomach in front of its closed part and the stoma to meet its commencement (Fig 221) It will be noted that the closed half of the stomach is merely covered by jejunum and is not separately infolded by a Lembert stitch

A retractor is now placed under the liver and interrupted sutures are placed to unite the afferent loop of jejunum with the deperitonealised part of the lesser curve These stitches bite first, the anterior antimesenteric border of jejunum second the posterior antimesenteric border of jejunum third the peritoneum at the posterior edge of the deperitonealised lesser curvature and finally the anterior edge of the lesser curve (Fig 222) When they are tightened the afferent jejunum lies neatly against the lesser curve of the stomach In retrocolic anastomosis about two and in antecolic anastomosis four or five such sutures are inserted The objects of these stitches are

1 To cover the deperitonealised lesser curvature
2 To relieve tension on the suture line at its most vulnerable point
3 By elevating the afferent loop to diminish still further the chances of food entering it.
4. To increase the valvular action

The final stages of the operation depend on the position of the anastomosis

If antecolic the afferent loop is inspected. It should run without distortion or tension to the lesser curve If very loose so that a loop tends to hang down then it should be lifted and fixed by interrupted sutures either to the remnants of the gastro-hepatic ligament, the left gastric pedicle or even the liver It must not be drawn and fixed to structures far to the right of the vertebral column (e g duodenal stump) or it will compress the colon Finally the transverse colon is drawn to the right, so that the antecolic jejunal loop runs opposite the splenic flexure which is well supported by the left phrenico-colic ligament and will not weigh heavily on it.

If the anastomosis is to be retrocolic in position, the stomach and jejunum are drawn down through the mesocolic opening and the unsutured edge of the latter is fixed with interrupted fine sutures high on the anterior stomach wall When the colon is replaced, the anastomosis is seen to lie snugly below the transverse mesocolon

Before closing the abdominal incision the surgeon should inspect the suture line splenic region, duodenal region epiploic vessels and other vascular pedicles to ensure their safety

BILLROTH I OPERATION

There are many ways of performing the Billroth I operation In particular it lends itself well to extensive resection of the lesser curvature with preservation of the greater curve The routine operation is described first

Standard Technique

The abdomen is opened and the operation proceeds as described for the Polya Hofmeister method until the duodenum is mobilised A light clamp such as the Lang Stevenson clamp is placed on the duodenum just distal to the pylorus or ulcer

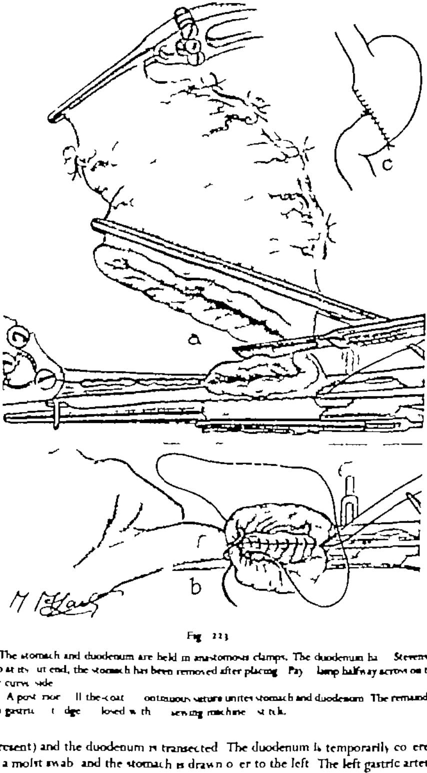


Fig 223

The stomach and duodenum are held in anastomosis clamps. The duodenum ha Stevenson clamp at its ut end, the stomach has been removed after placing Pay lamp halfway across on the lesser curve side

b A post rior ll the-coat ontinuous suture unites stomach and duodenum The remainder of the gastric t dge losed w th sewing machine st tch.

(If present) and the duodenum is transected The duodenum is temporarily co ered with a moist swab and the stomach is drawn o er to the left The left gastric artery is tied and the curvatures are prepared for anastomosis as already described The

stomach must be mobilised sufficiently to reach the duodenum without tension and any adhesion lateral to the duodenum must be freed to enable the duodenum to be drawn easily to the midline

A Lane clamp is placed on the stomach and its twin is applied to the duodenum so that when locked the lower margin of the duodenum is exactly opposite the greater curve of the stomach If the duodenal stump is short or fragile the Lane clamp may be omitted from the duodenal or both sides and the parts steadied instead with supporting ligatures

After the anti-soiling towel (Fig 219) has been placed around the clamps a continuous Lembert stitch unites the adjacent posterior surfaces of duodenum and stomach the stitch being locked at the upper margin of the duodenum A Payr crushing clamp is placed on the stomach from the lesser curve to the level of the upper limit of the Lembert suture A non-crushing clamp is placed across the whole diameter of the stomach just beyond this, and with a scalpel the stomach is transected cutting flush against the Payr clamp and leaving enough of a cuff on the greater curve side for subsequent anastomosis to the duodenum (Fig 223 *a*)

The part of the stomach under the Payr clamp is closed with a sewing machine stitch and the Payr clamp is removed The Stevenson clamp is taken off the duodenum and an all the-coats suture unites the posterior and then the anterior walls of the duodenum and the open part of the stomach (Fig 223 *b c*) Many stitches should be used to splint the anastomosis open—too few and too broad sutures will narrow the stoma Great care is necessary to take good bites of the stomach on either side of the knot which has completed the sewing-machine stitch If Lane clamps have been used they are now removed together with soiled instruments, swabs and towel, and the gloves are changed or washed

The closed part of the cut end of stomach is next inverted by a seromuscular suture This is commenced at the lesser curve and when the inverting stitch reaches the upper border of the duodenum it is ended by a triple bite of first anterior seromuscular coat of stomach second, posterior seromuscular coat of stomach and third superior seromuscular coat of duodenum This buries the so-called danger angle at the junction of the closed part of the stomach and the superior surface of the duodenum To render this point yet safer the posterior Lembert stitch uniting stomach and duodenum is continued round this angle and is then continued downwards as an anterior seromuscular suture burying the all the-coats suture line

No more than this is really necessary but if there remains the slightest tension a few sutures may be inserted to relieve it One suture may be placed to unite the right gastro-epiploic pedicle to the stomach A second stitch may be inserted between the right gastric pedicle and the stomach above the stoma The abdomen is closed in layers in the usual way

VARIATIONS OF THE STANDARD OPERATIONS TO MEET SPECIAL DIFFICULTIES

The commonest difficulties which require special treatment are severe scarring and penetration of a duodenal ulcer penetration of neighbouring organs by gastric ulcer and very high gastric ulcer A rarity is ulcer of the second part of the duodenum

Scarring and Penetration of Duodenal Ulcer

With repeated duodenal ulceration the resultant scarring causes shortening and narrowing of the affected part of the duodenum Quite small ulcers may be associated with extensive loss of duodenal tissue and though close to the pylorus they may also involve the junction of the first and second parts of the duodenum Multiple ulceration is common and ulceration may encircle the duodenum completely There is a tendency for duodenal dilatation to appear on the upper or lower parts of the duodenum or both between the pylorus and the narrowed part adjacent to the ulcer the so-called pre-stenotic diverticulum

For safe duodenal closure the surgeon aims at dissecting enough duodenum beyond the ulcer to permit of one all the-coats closure as well as a purse-string or Lembert layer It is advisable to dissect beyond and remove the duodenal ulcer not because of any particular danger in leaving the ulcer but because the ulcer usually causes such narrowing and is usually so close to the pylorus that if the duodenum is transected between pylorus and ulcer it is difficult or impossible to invert the duodenal stump into the narrowed duodenum

It is convenient to consider the first part of the duodenum as consisting of two segments The first segment is the more mobile part which has a posterior peritoneal coat in relation to the lesser sac The second segment lies between the point where the gastro-duodenal artery crosses the pancreas and the angle of junction with the second part of the duodenum Its posterior surface is unperitonealised and lies in intimate relationship to the pancreas to which it is attached by fine fibrous and vascular adhesions If the ulcer involves only the first segment then dissection beyond it is not difficult. If the posterior wall of the second segment is ulcerated, considerable difficulty may be experienced in mobilising a sufficient length of duodenum beyond it for good closure I have never found a case in which safe closure was impossible but the surgeon must be prepared for a slow and painstaking dissection which may occupy more time than the rest of the operation.

Anterior Wall Ulcers Should the ulcer be adherent anteriorly for example to gall-bladder liver or gastro-hepatic omentum such adhesions must be freed first In the case of completely penetrating ulcers this may lead to opening of the duodenum

Posterior Wall Ulcers Greater difficulty is experienced in dissection of posterior wall ulcers When the duodenum has been freed posteriorly the ulcer will be reached Care must be taken not to cut into the pancreas or the gastro-duodenal artery for the normal tissue planes are obliterated by fibrosis A little dissection leads to separation of the left edge of the ulcer crater from the pancreas so that the duodenal lumen becomes visible (Fig 224) The duodenal contents are aspirated and the area packed off to minimise soiling A finger may be introduced into the duodenum to determine the relation of the ulcer to the duodenal papilla. Freeing of the distal (right) ulcer edge from the pancreas is difficult because fibrous tissue from the ulcer edge and base has invaded the pancreas and the normal anatomical plane between duodenum and pancreas has disappeared Therefore the separation must be made by sharp dissection with a scalpel and a finger inside the duodenum will guide the surgeon in his endeavour to keep close to the duodenal wall instead of cutting into pancreatic tissue The ulcer floor which is in pancreatic tissue is not disturbed It needs neither to be excised nor cauterised for such a

procedure may lead to pancreatic leakage The floor is granulation tissue which has recently been bathed in acid antiseptic gastric juice At the most some antiseptic powder may be dusted into the crater The dissection need only continue for about a centimetre past the ulcer edge

Difficult Cases in Which There Is No Room for Duodenal Clamps The duodenum is transected with scissors opposite the distal edge of the ulcer and the end is closed with a running suture segment by segment as it is cut It is unnecessary to resect more ulcer edge than is required for neat duodenal closure although when the ulcer is very active the adjacent tissue is friable (That is one of the reasons why it is always worth while to give a week's medical treatment prior to resection in

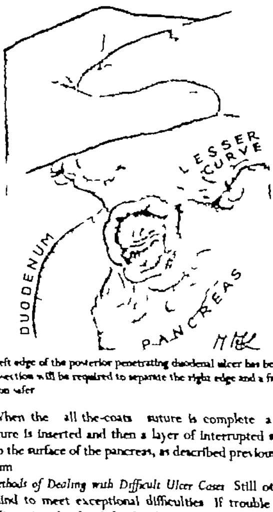


Fig 224. The left edge of the posterior penetrating duodenal ulcer has been separated from the pancreas. Sharp dissection will be required to separate the right edge and a finger in the duodenum will make dissection safer

ulcer cases) When the all-the-coats suture is complete a Lembert layer or purse-string suture is inserted and then a layer of interrupted sutures to turn the closed end on to the surface of the pancreas, as described previously under Closure of the Duodenum

Alternative Methods of Dealing with Difficult Ulcer Cases Still other methods must be borne in mind to meet exceptional difficulties If trouble is experienced or anticipated in dissecting the distal duodenal ulcer edge from the pancreas *Nissen's method* (1945) of suturing the cut duodenal edge opposite the crater to the undissected distal crater edge followed by the burying of the suture line in the ulcer crater (Fig 225) can be used By dissecting the circular pyloric muscle fibres from the duodenum it is sometimes possible to make a safe duodenal closure proximal to the ulcer

If it is recognized at an early stage that there is likely to be great difficulty in dealing with the duodenum, then a *prepyloric section and closure may be made* and a high gastrectomy performed, conserving the pyloric antrum. In view of the

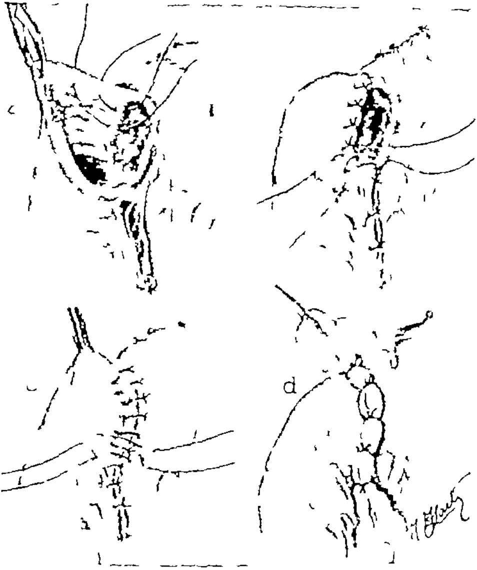


Fig. 2 5 The method advocated by Nissen for closure of the duodenum in cases of irremovable duodenal ulcer. W h interrupted sutures the anterior cut duodenal edge is sutured to the right edge of the ulcer crater to close the lumen. *A second row of sutures fixes the seromuscular* coat of the duodenum to the left edge of the ulcer crater (*b*) and a third row is placed between seromuscularis and pancreas ( ). The adjacent vascular pedicles may be drawn on to the closed duodenal end with the latter sutures (*d*). (Maingot, *Abdominal Operations*, 2nd Ed. By courtesy of Appleton-Century-Crofts, Inc.)

high recurrent ul rate which follow this operation it must be modified either by coring out the pyloric mucosa (Bancroft) or by a method particularly suitable *for the less experienced surgeon (or for the surgeon who dislikes the* coring-out

operation) This method consists in reoperating about six weeks after the gastrectomy and removing the antrum By this time the ulcer will have become inactive and antral resection will be found to be comparatively simple

Ulcer Involving the Second Part of the Duodenum

Chronic ulcer of the second part of the duodenum or of the angle between the first and second parts in which the first part is not involved, is not difficult to deal with so long as it is realized that it is unnecessary to remove the ulcer A high Polya Hofmeister gastrectomy should be performed, closing the duodenum proximal to the ulcer which thus excluded from the acid gastric chyme heals in a few weeks

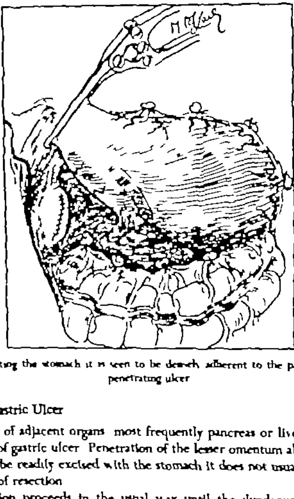


Fig 226 On lifting the stomach it is seen to be densely adherent to the pancreas around the penetrating ulcer

Penetrating Gastric Ulcer

Penetration of adjacent organs most frequently pancreas or liver is a common complication of gastric ulcer Penetration of the lesser omentum also occurs but as the latter can be readily excised with the stomach it does not usually add much to the difficulty of resection

The operation proceeds in the usual way until the duodenum is transected When the stomach is reflected to the left its area of fixation will be exposed (Fig 226) The ulcer area should be surrounded with pads to prevent soiling In very chronic cases a scalpel may be required to divide adhesions between the stomach and the penetrated organ, but in the majority of cases it is possible merely by pinching between the ulcer and the penetrated organ with finger and thumb to separate the two "Pinching off" is preferable to sharp dissection because the exact

junction of the stomach and the adjacent organ is exposed and thus the separation is avascular and without danger of damage to the penetrated organ Soon after separation commences the gastric lumen will usually be exposed, and a sucker is introduced to aspirate the gastric content By further pinching and perhaps occasional sharp dissection the ulcer edge in the stomach is completely freed from its floor in the adjacent organ As mentioned in the description of the operation for penetrating duodenal ulcer it is unnecessary to excise or cauterise the ulcer base

When the stomach is freed an opening bounded by the ulcer edge is seen in the stomach (Fig 227) This is temporarily closed with a running stitch to prevent further leakage and the gastrectomy is then continued in the usual fashion

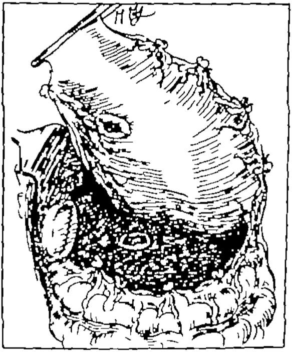


Fig 227 The ulcer edge has been pinched off The floor is seen in the pancreas.

High Gastric Ulcer

Clinical evidence has been presented to suggest that gastrectomy below a high gastric ulcer leads to ulcer healing (Colp and Druckerman 1946) Nevertheless, whenever possible the ulcer should be removed because the evidence that gastrectomy with ulcer excision leads to cure rests on firmer ground, and it has the advantage of obviating risks of bleeding, perforation and malignant degeneration

The operation is commenced as previously described in the routine operations the duodenum is transected and the left gastric pedicle is divided. If the site of left gastric ligation was not above the ulcer level then the fatty vascular and fibrous tissue continuous with the lesser omentum must be separated from the upper lesser curve to a point above the ulcer level Sometimes the ulcer is on the posterior surface of the stomach or less commonly anterior and all adhesions to the ulcer base must be freed

A point well down on the greater curve is chosen for the future anastomosis and from this point two Payr clamps are placed on half the diameter of the stomach. This point may be far below the ulcer level. The stomach is divided between the clamps and these are widely separated. Then two curved crushing clamps are applied from the tips of the Payr clamps upward to a point on the lesser curve above the ulcer level (Fig 228) and the stomach is divided between them completing the transection. Alternatively Schoemaker clamps can be used instead of the curved crushing clamps. In either case the surgeon must make sure that the clamps do not

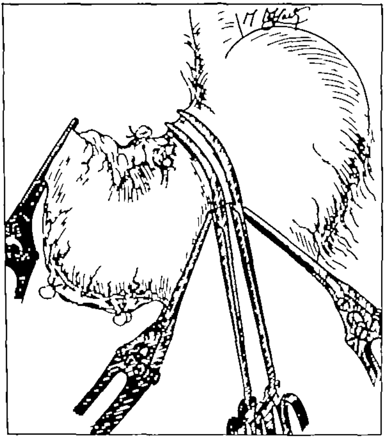


Fig 228 Two Payr clamps hold the greater curve half of the stomach and after incising between them two curved crushing clamps are made to arch above the ulcer to the lesser curve.

encroach on the oesophagus. If they are likely to do so the method must be varied as described later.

The part of the stomach in the curved crushing clamp is closed, using either a sewing-machine or continuous suture and the clamp is removed. This layer is then buried by a Lembert suture. This leaves a rather tubular stomach which can either be united end-to-end to the duodenum (Fig 229 *a*) or anastomosed end in side to the jejunum ante or retro-colic. Lane's clamps may be used in the final anastomosis if desired. If the stomach is anastomosed to the jejunum the afferent loop is fixed by interrupted sutures over the closed part of the stomach leaving a final result not unlike a Polya Hofmeister operation (Fig 229 *b*).

At times the ulcer is too high or too posterior to permit use of the two crushing clamps or Schoemaker clamp to remove the lesser curve In such cases a modification of the *Paucher operation* is convenient The dissection proceeds as just described up

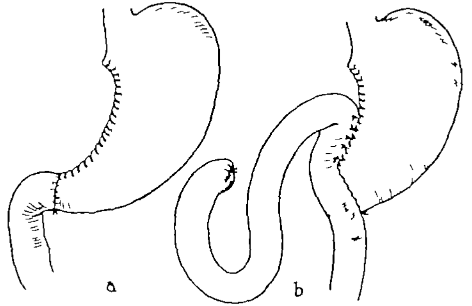


Fig 229 The tube-like gastric remnant can be anastomosed to duodenum ( ) or jejunum (b)

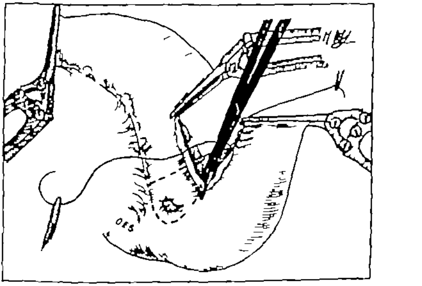


Fig 23 With the distal half of the stomach firmly lifted up with P yr lamp a tongue-like piece of the lesser urv containing the ulcer is removed A short segment is cut at time and immediately sutured w th continuous stitch

to the point where two Payr clamps are applied and the greater curve half of the stomach is di ided between them The stomach is surrounded with packs and then held well up with the Payr clamps The lesser curve is excised with scissors the

cutting being adjusted to remove more or less of the anterior or posterior wall according to the position of the ulcer The resection may be made high enough to excise an ulcer at the oesophageal margin It is advisable to insert a finger into the stomach to verify the position of the cardiac orifice This method may be used with less bleeding and soiling if the gastric contents are continuously aspirated and the cutting is done little by little each short segment being stitched with a running suture before further division (Fig 230) If the cardiac orifice is involved the suturing should be performed with a large stomach tube placed in the stomach by the anaesthetist When the lesser curve incision is repaired it is inverted by a Lembert suture and the operation is completed as a Billroth I or Polya Hofmeister gastrectomy If the oesophagus has been sutured, it is well to bring up the afferent jejunal loop and suture it over the closed oesophagus

This rather tubular form of stomach has excellent function and is comfortable for the patient With excisions as high as the cardia, transient dysphagia may be experienced but does not persist.

GASTRO-JEJUNOSTOMY

Gastro-jejunostomy is an excellent cure for duodenal ulcer but unfortunately in a high proportion of cases, probably between 20 and 30 per cent recurrent ulceration occurs at the gastro-jejunal stoma The operation is therefore generally reserved for the group of patients who are considered unlikely to develop recurrent ulceration or for patients who are too feeble for gastrectomy and require surgery so urgently that the risk of anastomotic ulceration is justified. Among the former group one should include patients who have developed obstructive symptoms following vagotomy although the question as to whether such patients would be better off with a gastrectomy remains *sub judice*

The Operation

An upper midline paramedian or a transverse incision is equally suitable The duodenum is inspected and palpated and the necessity for the operation is confirmed

The most favoured operation is the posterior short loop anastomosis The colon is lifted forwards and an area free of blood vessels is usually found to the left of or between the arches of the middle colic artery The fingers of the left hand press the lower part of the body of the stomach downwards and backwards towards the chosen area in the mesocolon The mesocolon is incised between forceps for 6 to 8 cm and the posterior surface of the stomach bulges through it The posterior surface is grasped with two Allis forceps or finger and thumb at a point near the lesser curve (caudad) in the rotated stomach and at a point near the greater curve (cephalad) (Fig 231) A Lane clamp is applied to the stomach between these two points The cut edge of the mesocolon is fixed to the stomach around the Lane clamp with interrupted sutures to prevent subsequent herniation into the lesser sac A loop of jejunum of equal length to the segment of clamped stomach and 6 to 8 cm beyond the duodeno-jejunal junction is fixed in the second Lane clamp and applied to the side of the stomach with the afferent loop toward the lesser curve (i e caudad) A two-layer anastomosis is made with continuous catgut and the clamps are removed When the stomach is replaced it will be seen that the efferent

jejunal loop is at the lower part of the greater curve so that gravity will assist gastric emptying

Antecolic anterior anastomosis will be preferable if the mesocolon is absent or deficient Generally speaking longer afferent loops will be required They will usually function satisfactorily if the stoma is transverse but if the stoma is oblique or longitudinal the efferent loop should be at the more dependent part

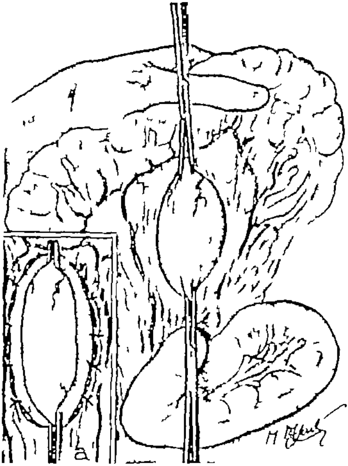


Fig 23 The fingers of the left hand press the posterior wall of the stomach through the mesocolic incision this is caught with Allis forceps and then (a) caught in Lane clamp

For a few years the writer (1946) has used an antecolic anterior juxta pyloric anastomosis in some cases of duodenal ulceration The anastomosis is made to the immediate prepyloric region the afferent loop being brought from under the splenic flexure of the colon, tacked across the stomach and anastomosed to the prepyloric region so that the efferent loop is dependent. The whole loop is then covered with omentum to prevent it adhering to the anterior parietes (Fig 232)

The *theoretical advantages* of this operation are

1 Jejunal mucosa is sutured to an alkali secreting mucosa—the antral mucosa.
2 As the stoma is not in the most dependent part of the stomach it is not bathed

between meals and at night with unbuffered acid peptic secretion as is the case in the posterior low operation

This operation will give a higher recurrent ulcer rate than high partial gastrectomy but in the small series performed by the writer it has been less than after the posterior short loop operation When recurrent ulceration does occur this operation is simpler to convert to a gastrectomy than is the posterior operation—a doubtful compliment!

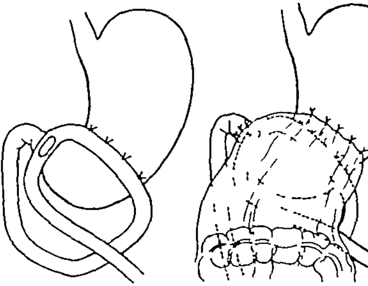


Fig 232 Anterior juxta-pyloric gastro-jejunostomy The stoma is in the pyloric antrum and the afferent loop is tacked with interrupted sutures to the body of the stomach to prevent angulation Finally the jejunal loop is covered by the great omentum which is also sutured to the stomach.

OPERATIONS FOR ANASTOMOTIC ULCERATION AND GASTRO-JEJUNO-COLIC FISTULA

The operation of choice for recurrent ulceration after gastro-jejunostomy is high partial gastrectomy with a Polya Hofmeister reconstruction In young persons vagotomy may be combined with this procedure for the convalescence after vagotomy combined with gastrectomy is smoother than when it is combined with gastro-jejunostomy

GASTRECTOMY FOR STOMAL ULCERATION FOLLOWING GASTRO-JEJUNOSTOMY

A generous longitudinal incision is made preferably through the old incision, but passing directly through all the coats even though the previous incision may have been a muscle-displacing one If a fresh incision is made it will probably lead to fresh adhesions on its peritoneal surface and as the division of the adhesions below the old incision can rarely be avoided, nothing is gained by the second incision When the peritoneal cavity is opened—and this is most easily done at the upper or lower prolongation of the old incision—adhesions between parietal peritoneum

liver duodenum stomach and colon are made tense and divided with a sharp scalpel

The original duodenal ulcer will almost invariably be found to be healed though there may be considerable narrowing The stoma and adjacent stomach and jejunum are carefully examined for ulceration or ulcer scarring

The mesocolic opening (presuming the previous operation to have been retrocolic) is separated from the stomach and from the ulcer great care being taken to avoid damage to the mesocolic vessels It is convenient next to free the greater curvature of the stomach tie the right gastro-epiploic and right gastric vessels and

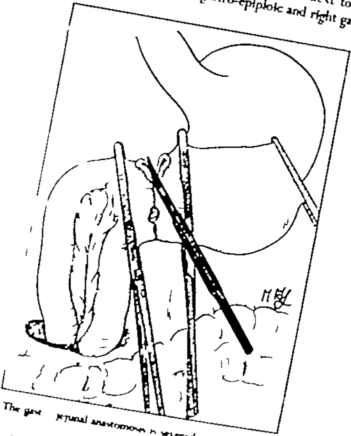


Fig 33 The gast jejunal anastomosis is severed in the exact line of union.

to transect the duodenum at it narr west part and close it as al eady described. On drawing the t oma h t the left the ga t jejunal anastomosis omes well into view

After freeing an lesser sac adhesion the surgeon places non-crushing clamps on the t ma h and the jejunal loop on e ther ide of the anasto jejunostomy undone by carefully cutting through the exa (Fig 233) If this plane of division is accurately followed p point are enc unt l though The gastro-

When jejunum nd t mac tomosis closed by sutur or vered w usually found at son bleeding ulcer crater x ised It will be ed the gastric he stoma Jejunum is exa porarily mewhat defo n small ing and

distension but it will be possible in 90 per cent of cases to close the jejunal stoma by suturing what was a longitudinal incision transversely in two or three layers The closed jejunum will be found to be sufficiently patent for its subsequent function i e as a duct for the passage of bile pancreatic and duodenal juices

If the jejunal scarring is severe or if there is ulceration on its mesenteric side it is wise to resect the affected part and perform end-to-end anastomosis This applies even more to long-loop or antecolic anastomoses where the sutured jejunum is likely to be in the efferent loop of the subsequent gastrectomy

A Polya Hofmeister gastrectomy is now performed in the manner previously described If antecolic the mesocolic aperture should be closed by suturing

There are innumerable variations in the method of converting a gastro-jejunal anastomosis into a gastrectomy The method described is one used by the author over fifty times without mortality

OPERATION FOR GASTRO-JEJUNO-COLIC FISTULA

The three main problems in dealing with gastro-jejuno-colic fistula are

1 The dehydrated and starved state of the patient which makes him less likely to withstand a major operation and more prone to intercurrent or post-operative infection
2 The faecal contamination of the stomach, which makes surgical intervention more likely to be followed by peritonitis and involves a risk of inhalation pneumonia
3 The need for colon repair

To these problems are sometimes added the less urgent complications of subacute colonic obstruction and severe proctitis

The technical procedure is only slightly more difficult than that necessary for gastro-jejunal ulcer The main consideration therefore is not the undoing of the fistula but the preparation of the patient for operation

Preparation of the Patient

The restoration of lost nutriments by parenteral routes must be pursued vigorously Intravenous saline glucose and amino acids are given daily Plasma and whole blood will correct any anaemia and also help to restore the blood protein level Although there is as a rule no specific vitamin deficiency disease symptoms of deficiency are liable to be provoked by the slightest stimulus, and particularly by operation Therefore parenteral injections of thiamine nicotinic acid riboflavin, and ascorbic acid are particularly important.

The patient is often ravenous—and high-quality food, protein especially should be given by mouth, for some may pass through the jejunum The anal region should be well smeared with petrolatum as protection against irritation by the acid discharged

Preliminary Proximal Defunctioning Colostomy

I believe that proximal defunctioning colostomy is the best form of preparation for the main operation After it, faecal vomiting and eructation cease and the colon and stomach become clean enough to make colonic and gastric surgery free of the

danger of peritonitis from soiling. In addition, the nutrition of the patient may improve quite considerably after colostomy owing possibly to the fact that the contracted non-functioning colon is less likely to receive the gastric content, and thus more will enter the jejunum.

Technique

In view of the state of the patient and the highly infective gastric content, it is safer to make the colostomy under local anaesthesia. Simple infiltration of all the layers in the line of incision is adequate, or the intercostal nerves may be blocked just below the right costal margin.

An incision passing from the 10th costal cartilage on the right side downwards and medially, splitting the subjacent muscle in the line of their fibres, is made, or a short muscle-cutting subcostal or transverse incision may be used.

The right part of the transverse colon or the hepatic flexure is brought forwards and a double-barrelled colostomy is made by inserting a glass rod through the mesocolon and placing two or three seromuscular sutures to fix the sides of the loop together. The wound is closed in layers. The colostomy is opened twenty-four to forty-eight hours later, but the glass rod is left in until three days after the colon has been separated from the stomach.

Great judgment is required to decide when the patient has gained the maximum benefit from the colostomy. He has usually reached the peak of improvement in about fourteen days. Sulphasuxidine is given by mouth to complete the colonic sterilization. Colon lavage is usually unnecessary in view of the flow of gastric juice through it.

Technique of Disconnection of the Fistula

As the stomach is now free of faecal material, general anaesthesia is permissible.

A generous incision is made, preferably directly through the old scar, and all peritoneal adhesions are freed. The mesocolon is freed from the stomach and the fistula is defined and packed off from the general peritoneal cavity. Non-crushing clamps are placed on the colon on either side of the fistula and on the stomach and jejunum around the fistula, and the fistula is disconnected by "pinching off" the ulcer, or with a scalpel through the plane between colon and jejunum. The jejunal opening is covered with a pad. The colon is examined. If the opening is small and there is no stenosis it is closed by a few transverse all-layer sutures reinforced by Lembert sutures and a pad of omentum. If there is some stenosis of the colon, longitudinal incision is made from each side of the fistula and the resultant longitudinal incision is stitched up transversely in two layers, leaving a wide passage, after the fashion of a Heineke-Mikulicz pyloroplasty. I do not think colectomy is necessary unless the blood supply to the affected colon is damaged in the separation, as sometimes occurs, or unless the fistula encroaches on the mesenteric border of the colon.

The gastro-jejunal anastomosis is completely freed from its adhesion to the mesocolon and lifted upward.

If the patient is feeble and the duodenum is not obstructed, the gastro-jejunostomy is undone and the stomach and jejunal openings repaired (or a segment of jejunum excised if it is severely damaged). If the patient is in reasonable condition, or if the

duodenum is stenosed the gastro-jejunostomy is dismantled and gastrectomy per formed as described under Gastro jejunal Ulcer

Post-operative Period

The parenteral feeding is continued until the patient can take adequate protein food by mouth usually in three to four days

Occasionally the diarrhoea will persist after operation This may be due to damage to the cells of the intestinal mucosa resulting from starvation— starvation diarrhoea —and is an indication for increasing protein foods and persisting with intravenous amino acid and plasma infusions.

The glass rod is removed from the colostomy on the third post-operative day The colostomy retracts considerably It may be closed using an extraperitoneal method about three weeks after operation

ACUTE PERFORATION OF PEPTIC ULCER

Until recent years, the treatment of perforated peptic ulcer by immediate laparotomy closure of the perforation and peritoneal drainage has been the undisputed method of treatment. The mortality associated with surgical treatment was dependent on the delay before operative closure of the perforation took place Few other factors influenced the mortality the method or skill used in closure playing little part though there has been a general downward trend in mortality since the introduction of effective chemotherapy

Weighing up of the pros and cons has led to the discarding of peritoneal drainage in earlier cases for the secretions are largely protective in function and much of the discharge from drainage tubes is from the granulation tissue in their track. Further disadvantages of tube drainage were that it led to peritoneal adhesions and occasionally resulted in incisional hernia More attention is now paid to gentle mopping out of fluid and food debris from the peritoneal cavity at the time of operation and drainage is retained only for cases with pelvic abscess late cases or where there is extreme soiling, for example after perforation of stenosed ulcer or carcinoma

Two opposing trends have developed of late years On the European continent the treatment of perforation by immediate gastrectomy has gained quite considerable support (Yudin 1939) and in England a few surgeons have had satisfactory results from the non-operative treatment of perforated ulcer (Taylor 1946)

Immediate Gastrectomy for Perforated Peptic Ulcer

The main argument in favour of this rather drastic treatment is that the chance of further ulcer trouble is greatly diminished by the operation (It is possible too that the lack of gratitude often shown by the patient whose ulcer relapses after ulcer suture plays some part.) The operation is restricted to early cases in good general condition with a history of chronic ulceration other cases still being dealt with by simple suture There is no doubt that good recovery rates are often obtained from emergency gastrectomies in selected cases

This procedure for perforated ulcer has not become popular in England or America, for I believe the following reasons

No indisputable statistics have been given showing that immediate gastrectomy

lowers or equals the mortality figures obtained after simple suture. Figures comparing the mortality after simple suture in *all cases* with the mortality of gastrectomy in the *good risk cases* cannot be accepted

2 There is a readily understandable tendency to resect the easy acute ulcer rather than the difficult chronic penetrating ulcer although the latter is more likely to produce ulcer trouble later

3 These operations are often done by very junior surgeons, or by surgeons who have little experience of gastrectomy

Where conditions are good, the surgeon an experienced gastrectomist, the *perforation recent the peritonitis about the perforation localized, and the ulcer chronic* then resection is justified

Non-operative Treatment of Acute Perforation of Peptic Ulcer

Many surgeons have had the experience of finding a perforated ulcer already well sealed by fibrinous adhesions or omentum or by a contiguous structure when exposed at operation Patients with perforated ulcer who refuse surgery occasionally *recover As a natural sequence of these experiences some surgeons have treated* undoubted cases of perforation conservatively The patient is given morphine and the stomach is emptied with a large stomach tube and kept empty by continuous suction through a soft indwelling oesophageal tube Fluids are withheld orally but water electrocytes and glucose are given intravenously After twenty-four to forty-eight hours gastric aspiration is discontinued and oral feeding is cautiously instituted

Results have been recorded which show mortality and morbidity figures comparing well with those obtained by operation Where opportunities for early surgery are absent or limited it is a method which should be used. Further careful statistical analysis must be given before the method is adopted as a satisfactory method of treatment under normal circumstances Certainly good risk cases are occasionally lost from persistent leakage when non-operative treatment is employed

Suture of Perforated Peptic Ulcer

There should be as little delay as possible before operation but on the other hand the patient should not be rushed from ambulance to theatre As soon as the diagnosis is confirmed and the decision to operate is made 16 mg ($\frac{1}{4}$ grain) of morphine is given together with 0.4 mg ($\frac{1}{150}$ grain) of hyoscine or 0.6 mg ($\frac{1}{100}$ grain) of atropine If shocked the patient is wrapped in warm blankets though excessive heat should be avoided and a slow intravenous drip saline or plasma infusion may be given As a result of these measures the patient loses much of his pain and is usually fit for surgery in a half to one hour If deterioration steadily continues despite these measures it is unlikely that surgical interference will be of much avail though if the abdomen is intensely distended paracentesis abdominis to let out gas and fluid may then produce enough improvement to permit surgical closure of the perforation

The anaesthetic is left to the discretion of the anaesthetist There is no evidence that the post-operative pulmonary complications which often follow ulcer perforation are due to the form of anaesthesia used they are more likely to be due to the

abdominal and lower chest immobility resulting from the peritonitis In gravely ill patients however local anaesthesia is advisable

Technique of Closure of Perforation

An upper abdominal incision is made starting about 3 inches below the costal margin

As the peritoneal cavity is opened gas and fluid escape A sucker is introduced to aspirate the excess of fluid with particular attention to the pelvis and Morison s pouch

The liver is retracted upward and first the duodenum and then the stomach is inspected for the perforation (Fig 234) If the perforation is not found the posterior

Fig 234. Exposure of duodenal perforation.

gastric wall is examined from oesophagus to duodenum after opening either the gastro-hepatic or gastro-colic omentum preferably the former

It makes little difference to the immediate result how the perforation is closed a simple purse-string suture or two or three Lembert stitches give quite satisfactory results As the tissues adjacent to the ulcer are very friable stitches close to the ulcer tend to tear out and it has become customary to omit stitches passing through all the layers Normal healing of an ulcer largely depends on contraction of the fibrous floor drawing the ulcer edges together The writer believes that this process of healing can be materially aided and the likelihood of stenosis diminished if all *the-coats stitches are placed in such a way as to* draw the ulcer edges together in a line at right angles to the bowel Outside this is inserted a layer of very widely placed Lembert stitches with pads of omentum drawn under them (Fig 235) In order to

make closure more secure and to deepen the tissues under the ulcer thus diminishing the chance of recurrent perforation

In difficult cases it is recommended that a plug of omentum be inserted into the perforation This method should not be used too freely as it probably diminishes the rate of ulcer healing by interposing a foreign body between the mucosal edges of the ulcer

At times the perforation involves only a minute part of the edge of a large penetrating ulcer If there is no concomitant haemorrhage then the perforation should

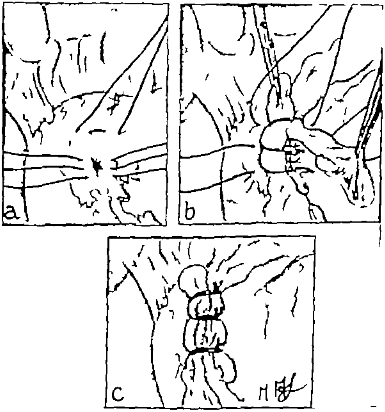


Fig 235

Three interrupted stitches draw the ulcer edges together

b Wide Lembert stitches are placed on either side and pads of omental fat are drawn from above and below to lie under the Lembert stitches

c The closure completed

be sealed by fixing omentum over it and if possible one or two Lembert stitches or a purse-string suture to reinforce it The patient should be re-investigated in six weeks when, if the ulcer is unhealed gastrectomy will be advisable

If it is believed that closure of a duodenal ulcer will increase an existing stenosis or cause stenosis two courses are open The first is to perform a gastro-jejunostomy the second is to convert the perforation into a pyloroplasty For the latter a longitudinal incision 3 to 4 cm long is made from each side of the perforation, usually dividing the pylorus and the incision is stitched up transversely after the fashion of Heineke-Mikulicz pyloroplasty The suture line should be reinforced with omentum

OPERATION FOR BLEEDING PEPTIC ULCER

It would be outside the scope of this contribution to discuss the indications for surgery for bleeding peptic ulcer but it may be said that two policies are open to the clinician The first is to operate at once on all cases of massive haemorrhage where it is known that an ulcer is present The second is to follow a policy of selective surgical intervention that is to say to operate only on those who are considered to be in grave danger of dying from haemorrhage

The nature of the surgical procedure will vary according to the policy followed for in the case of immediate surgery the patient will usually be in good general condition at the time of operation and the operation of choice will be the one which will not only arrest the bleeding but also give a good chance of curing the ulcer—that is gastrectomy Under the latter policy surgery will be undertaken later usually after a second haemorrhage or after a period of continuous bleeding and the patient s condition will be deteriorating In these circumstances the surgeon should perform the smallest operation that will arrest the bleeding

Technique of Operation for Gastro-Duodenal Bleeding

Blood transfusion will usually be required pre-operatively and should always be in progress during the operation Fluid and salt deficiency is sometimes present and should be corrected by intravenous infusions Peptic ulcer patients are prone to develop vitamins B and C deficiency and injections of these vitamins are therefore given prophylactically

As anaemia leads to a lowered resistance and infection prophylactic chemotherapy with penicillin or a sulphonamide should be commenced pre-operatively

The writer always uses local anaesthesia in dealing with this type of case, but general anaesthesia should be used by surgeons who are not well accustomed to working with local

A high long, mid-epigastric incision gives good exposure and can be made with minimal blood loss Excessive vascularity of the wound will give rise to suspicion of portal hypertension A general examination of the viscera is made Ascites hepatic cirrhosis splenic enlargement and dilated portal veins will be looked for The colon usually appears blue from its content of altered blood

Finally the stomach and duodenum are carefully examined This examination must not be perfunctory even if portal hypertension is present for occasionally peptic ulceration and cirrhosis of the liver may occur together When this obtains haemorrhage may be the first indication of the presence of the ulcer

The stomach duodenum and abdominal oesophagus are first palpated and then inspected.

Palpation in most cases reveals an ulcer crater without difficulty but where a crater is not at once obvious, the most careful palpation is necessary A superficial ulcer may be impalpable but some thickening from fibrosis may be detected. I have twice failed to feel an ulcer but instead felt an object like a bristle head in the stomach wall In each case this turned out to be a sclerotic open vessel end in a shallow small ulcer crater!

Areas of wider induration give rise to suspicion of neoplasm The possibility of benign tumours must be kept in mind and careful palpation made for soft polypoid masses which may be mistaken for thickened folds or for hard connective tissue tumours which may slip away from the examining finger

Palpation of enlarged glands sometimes points to the site of an impalpable ulcer. Inspection is equally important. Ulcers which cannot be felt are sometimes seen as a scar or deformity of the serosa or as a surface roughening or blush. Not only

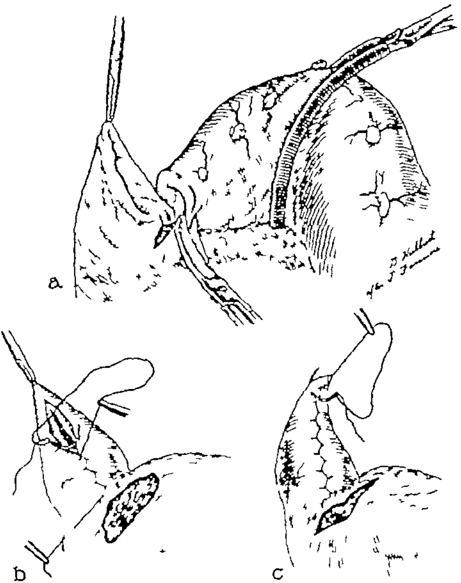


Fig 236 Yudin method for difficult bleeding duodenal ulcer The duodenum is transected obliquely conserving cone of duodenum opposite the ulcer crater ( ). After suture of the closed end (b) the resulting duodenal cone is turned towards the ulcer crater (d f g) and finally sutured in (h (From British Journal of Surgery 946 Vol 33)

the anterior but the posterior surfaces of the lesser curve of the stomach and of the duodenum must be visualised after division of the gastro-hepatic or gastro-colic omentum The upper posterior gastric wall is seen best by rotating it to the right, the lower gastric wall by upward rotation and the duodenum through the gastro-

colic ligament Any pathological adhesion is noted but the normal gastro-pancreatic and gastro-mesocolic adhesions will have to be divided to view the posterior wall

If no pathological lesion is found after this examination three courses are open to the surgeon

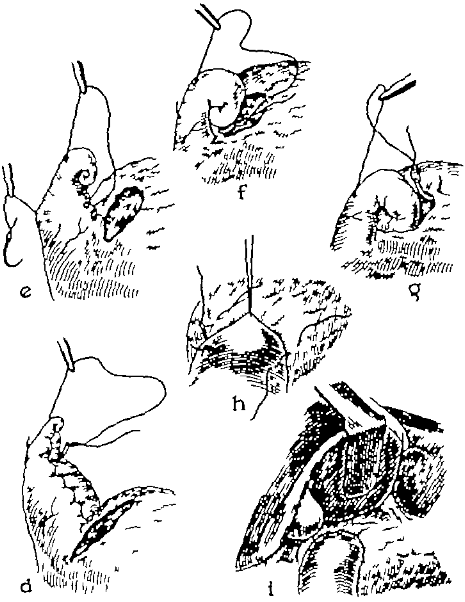


Fig. 136.—*Continued*

1 To perform high partial gastrectomy
2 To explore the interior of the stomach through a gastrotomy wound.
3 To adopt some intermediate solution—for example to ligate the four main gastric arteries

I am averse to the first solution unless other evidence, e.g clinical or past history points to gastric disease

Gastrotomy is advisable if there is severe bleeding, but if the bleeding is recent and moderate the vascular ligature is usually satisfactory

Exploratory Gastrotomy

The stomach is carefully packed round with pads, and the ends of the proposed incision, a longitudinal one in the pyloric antrum are held with Allis forceps The seromuscular coat is first divided and then all vessels seen are picked up with fine forceps divided, and ligated On opening the mucosa the gastric contents are aspirated and their character noted Large clots may be removed with sponge forceps

When the stomach is reasonably empty two deep broad bladed retractors are inserted and the gastric mucosa is examined with the aid of a strong light an otologist s head lamp is useful for this purpose

Special care is taken not to miss minute erosions, small innocent tumours, diffuse mucosal bleeding, or varices of the stomach or cardiac region

If no abnormality is found in the stomach, the gastrotomy incision may be extended across the pylorus and the duodenum similarly examined Small erosions may be dealt with by diathermy coagulation, but if multiple and confined to the lower stomach with also a history of recurrent attacks of bleeding, then gastric resection is justifiable Sometimes the erosions extend far down the alimentary tract.

Technique of Arrest of Ulcer Haemorrhage

If a gastric or duodenal ulcer is present and the patient is in good condition then gastric resection is the most certain means of arresting the bleeding and should be carried out.

If the ulcer is very high the expert gastric surgeon will usually have no difficulty in performing a Pauchet modification to include the ulcer though local excision of the ulcer would be justifiable

In the case of difficult posterior duodenal ulcer Yudin s (1939) method of closing the duodenal end obliquely with the antimesenteric side conserved in a cone shape and then rolling this conical shaped end into snail-like form and burying it in the ulcer crater is possible (Fig 236) Generally in such difficult cases however I am in favour of duodenotomy and underrunning the crater with silk ligatures.

In less robust cases other methods of treatment are available Ligation of the vessels entering the ulcer base from outside the stomach or duodenum is often difficult and hazardous particularly in the duodenum and not very reliable in view of the uncertainty as to which particular vessel is eroded.

Ligation of the Vessel in the Ulcer Base

This is valuable particularly where resection would be difficult, e g gastrojejunal ulceration It is usually safer to suture the edges of the crater firmly together than to ligate friable tissue in the ulcer base In the case of smaller gastric ulcers and duodenal ulcer this is done after gastrotomy or duodenotomy Difficulty arises in dealing with a giant gastric ulcer the edges of which are fixed wide apart. In such ulcers which are always completely penetrating, the ulcer should be pinched off the penetrated organ, and then the edges of the resulting opening in the stomach

firmly sutured, taking care that the sutures bite widely enough to compress the ulcer edges In the majority of cases the bleeding vessel lies in the edge but must sometimes be caught in the ulcer base This procedure may lead to gastric obstruction, and gastro-jejunostomy may be necessary It is undoubtedly a life-saving measure in the occasional feeble patient with a bleeding giant gastric ulcer

Duodenal ulcers are approached by a longitudinal incision in the duodenum over the ulcer with precautions against soiling and bleeding mentioned under Exploratory Gastrotomy Retractors are inserted to view the ulcer As in all these opera-

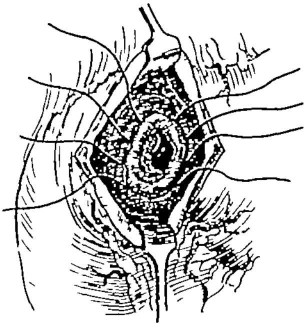


Fig 237 Deep sutures are made t underrun the ulcer base and edges.

tions loose clot in the ulcer must not be disturbed as at times violent bleeding occurs when it is removed Deep stitches of non-absorbable material which are used to underrun the ulcer crater and edges (Fig 237) are then pulled tight

The duodenum is resutured longitudinally in two layers and repair reinforced with omentum. As this usually obstructs the duodenum posterior gastro-jejunostomy must also be performed

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CHAPTER 18

Hypospadias

DENIS BROWNE

PATHOLOGY

THERE ARE several different elements in this deformity It is not a simple failure of fusion like a cleft palate

1 *The cleft of the prepuce* This exists in all degrees of the deformity but is of no functional importance and causes only a slight departure from the normal appearance

2 *Narrowing of the meatus* This occurs most frequently when the opening is slightly misplaced proximally from its normal position. When an opening of this sort is close under the glans there is invariably a small blind sinus distal to it, which has considerable importance in treatment

3 *Imperfect floor to the urethra* In many cases in which the urethra has not formed properly with a consequent lack of its proper length its terminal portion is floored merely by a thin sheet consisting of skin intimately fused with the mucosa lining the tube If this is not noticed and treated it can hamper any form of operation

4 *Shortening of the under surface of the penis* This element of the deformity is unexplained The corpus spongiosum fails to form and in its place there is found tough contracted fibrous tissue which holds the penis bent down in a curve which is of course exaggerated when erection occurs into a marked chordee In certain rare cases this failure of development of the corpus spongiosum and consequent permanent bending down of the penis may occur without any displacement of the meatus from its normal position, and without any shortening or narrowing of the urethra

5 *Displacement of the opening of the urethra* The urethra may open anywhere along its normal track from the glans to the perineum In the more extensive displacements the scrotum is of course cleft producing the well-known resemblance to the femal and in these the posterior part is a deep cleft lined with red mucous membrane

In a not uncommon form of hermaphrodite a rudimentary vagina opens into this cleft behind the urethral meatus

6 *Post-operative fistulae* These are only too common as the result of treatment They differ from similar fistulae elsewhere in the body in being lined with epithelium indistinguishable from that of the surrounding normal surface and in not being encircled by scar tissue with its inevitable tendency to contract In consequence they have no tendency to close spontaneously It will be seen that these fistulae have just the properties desired for an artificial urethra, and it is on this curious immunity of the penile skin and subcutaneous tissue from keloid or contraction that the recommended operation is based It consists in fact in the deliberate formation of a fistula to end all fistulae

THE REQUIREMENTS OF THE OPERATION FOR CONSTRUCTING A NEW URETHRA

If these are stated it will be seen that no operation previously put forward fulfils them

1 It should be applicable to the severest degrees of the deformity as well as the slighter ones

2 It should be capable of regular completion before the age of 5 years at which most patients will begin school The importance of this to the child psychologically is immense

3 It should produce a urethra which will allow the insertion of a full-sized cystoscope It is obvious that if this is not possible the patient might in certain circumstances, be gravely handicapped Grafted tubes tend to be too narrow and rigid for this.

4. It should be applicable to post-operative fistulae of whatever size

5 It should not make the new urethra of hairy skin because of the tendency to calculus formation upon the hairs

6 It should not involve risk of irreparable disaster to the function of the penis by cutting into the erectile tissue

7 It should divert the urine completely from the operation area during the process of healing Apart from the danger to the success of the operation from the newly sutured tissues being flooded with urine at high tension, early urination is intensely painful

8 It should provide a free exit for tissue fluids so avoiding the extreme oedema which is one of the post-operative difficulties of this region

9 It should allow the increase in length and diameter caused by erections to be taken up without strain on the suture lines.

10 It should employ sutures which have no tendency to cut the extremely fragile skin

11 Finally it should not be too difficult or complicated for the average competent surgeon to perform with a high prospect of complete success

TECHNIQUE OF OPERATION

1 Cleft Prepuce

All this needs is a semi-circumcision to make the penis look like an ordinary circumcised one It is actually not difficult to mend the cleft in the ventral surface

If this should for any reason be desired and the skin is not needed for the construction of a new urethra The prepuce should never be removed until it is quite certain that the skin will not be needed.

2. Narrowed Meatus in Glandular Hypospadias

The small distal blind sinus already described should be identified and one blade of a fine blunt pointed scissors thrust into it as far as possible The other blade is inserted into the urethra and the scissors closed to throw the two tubes into one This simple trick will enlarge the opening to the necessary size without shortening the already too short urethra and will leave the penis so close to normal in both appearance and function that nothing more is necessary

3 Narrowed Meatus in Penile Hypospadias

The floor of the urethra should be slit down freely and the skin and mucosa joined *by three small catgut stitches The enlarging cut should err if at all on the side of* generosity an extra quarter of an inch does not add in the least to the difficulty of *operation, whereas an insufficient widening here would spoil the perfection of the* new urethra

4. Imperfect Floor of the Urethra

Whatever the size of the opening, if the floor is not of proper thickness but merely the thin transparent approximation of skin and mucosa already described it should be slit back to where it becomes normal as a preparation for constructing the new urethra If this is not done the necessary deep burying of the new tube becomes impossible

5 Contracted Under-Surface of the Penis with Normal Position of Meatus

In this rare condition it is possible to cut the skin and contracted fibrous bands transversely across just below the glans It will then be found that the urethra itself is not contracted enough to prevent full extension of the penis and all that is necessary is to sew up the skin gap longitudinally If the urethra should have been opened *bladder drainage is needed, and if there is any tightness of the penile skin it can be* relieved by a dorsal slit

6 Contracted Under Surface of the Penis with Displaced Meatus

A transverse incision in the skin just below the glans should be made on the ventral surface of the penis continued widely out into the prepuce on either side The rudimentary corpus spongiosum should then be peeled away from the main body of erectile tissue deep to it and thrust down towards the base of the penis taking with it the meatus The short thick fibrous bands on either side of the chordee are divided and the skin edges sutured longitudinally with fine catgut Care should be taken that the meatus is sutured firmly in its new position to the bared corpora cavernosa otherwise it may protrude in an awkward lump A dorsal slit is made in the penile skin and prepuce to do away with tension and a dressing of ribbon gauze applied and soaked in acriflavine and paraffin This dressing is left on for a week or so and ensures healing in the correct shape of the penis No

bladder drainage is necessary This is the first stage of the operation the second follows in No 7

7 Displaced Meatus, of Any Degree

Bladder Drainage Suprapubic drainage is unsatisfactory as the sphincter is apt to open and allow the proximal urethra to be filled with urine which is then emptied downwards by the contraction of the compressor urethrae Perineal drainage by means of a Malecot catheter is much better The catheter is thrust into the bladder on a sound which protrudes in the perineum (Fig 238) The catheter is then cut down upon through a small incision preferably by a diathermy knife As soon as a small portion of rubber is seen at the bottom of the incision the cutting is stopped

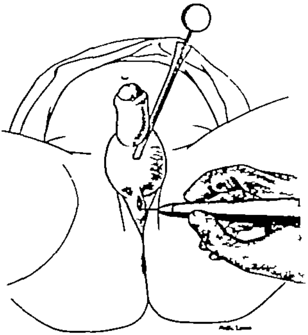

Fig 238 Incision for perineal drainage of the bladder The head of the Malecot catheter is in the bladder and the middle of its shaft is being forced out through the skin by the reversed sound. *It will be found convenient to cut the dilated end off the catheter*

and the point of the sound used to thrust the catheter out. In this way the opening is kept small and so closes rapidly when the catheter is finally withdrawn

The catheter is then stitched to the skin by two linen sutures, tied tightly round the tube and loosely in the skin so that they do not cut out. If this is not done even the best behaved child may pull the catheter out particularly when half asleep

The end of the tube is then connected up to a reversed Wolff's bottle giving a suction of about a foot of water which will be enough to keep the bladder empty without discomfort

Incisions Around New Urethra The new tube is left to be formed by the remarkable local healing processes already described from a simple strip of skin, buried as deeply as possible under the outer epithelium This strip is outlined by an incision that encloses the meatus proximally and then runs out to the glans (Fig 239)

The skin is raised freely by scissors dissection completely around the meatus and the strip until the edges can be lifted free and come easily together like the sides

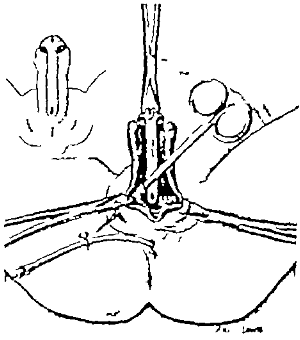

Fig 239 Outline of incision for penoscrotal hypospadias dissection of the lateral flaps that are to over in the strip of skin that is to form the new urethra; and formation of drainage outlets through the halves of the scrotum

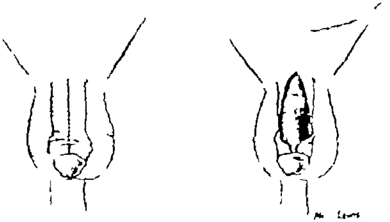

Fig 4 Line of dorsal incision for relief of tension on the penile skin, and sketch of the bare area that may be left to heal over

of a loose double-breasted coat This radical freeing of the lateral flaps is of the utmost importance as any tension in bringing them together will wreck the operation. A triangular piece of the glans is made raw on either side of the situation

as that would produce necrosis of the delicate skin in their grasp The beads should be brought together and then the one to be fastened withdrawn at least ½ inch before the suture stop is clamped down.

Skin Sutures The skin edges of the cleft are now brought together with extremely fine and carefully applied sutures of catgut taking the minutest possible grasp of their edges There should be no tension whatever upon this line the sutures merely having the task of adjusting and preventing inversion (Fig 242)

Finally the newly constructed ventral surface of the penis is pulled well up on to the glans so that its raw under-surface is against the raw patches made on either side of the new meatus, and there it is sutured firmly into position

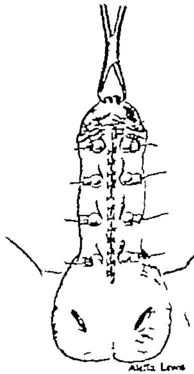

Fig 242 The completed operation.

Dressing This is simply a spray of penicillin and sulphonamide powder the operation area being otherwise left open to the air This powder mixed with exudate produces an antiseptic scab of the kind approved by Lister and healing proceeds very well under it.

After Treatment Penicillin injections are kept up for the first week after operation the aseptic healing usually obtained by them being well worth the extra discomfort The tension sutures are removed at the end of the week by cutting between the two elements of the stop As the beads by this time are usually embedded more or less deeply in swollen and serum skin the advantages of this method of cutting are obvious The drainage of the bladder is kept up for ten days and the opening in the perineum usually closes within three to five days later

CHAPTER 19

Aseptic Intestinal Anastomosis

A K MONRO

An aseptic anastomosis is one in which the previously rigid aseptic routine of laparotomy is not broken—one in which, in fact no bacteria are allowed to leave the intestine It contrasts with the open anastomosis in which the two ends of bowel are laid open and are then sutured By careful technique the soiling of the peritoneal surfaces inherent in the open method may be slight but, however skillfully performed, some soiling of the peritoneal surfaces of the bowel is inevitable Particularly in patients whose resistance is from any cause lowered, this soiling may be a cause of frank infection It may result in ileus the abdominal surgeon s greatest enemy for even the most carefully executed anastomosis will not stand stretching At least it will be followed by adhesions which may be troublesome

HISTORICAL DEVELOPMENT

The story of intestinal anastomosis is a fascinating one Early efforts were followed by an enormous mortality In 1892 the majority of surgeons turned gratefully to Murphy s button which was undoubtedly at that time a great advance It was repeatedly written that the technique of coeliotomy was good until the bowel was opened but that thereafter soiling occurred and infection and deaths ensued

Bulkhead Method of Parlavecchio and Halsted

In the closing years of last century many methods were devised which are now of historical interest only The first real advance was made by Parlavecchio who first used the cautery to divide the bowel In 1897 he described his method of anastomosis In it he closed each end of the bowel with a simple ligature then sutured all round the intended anastomosis leaving only a small opening through which the two occluding ligatures were lastly divided. This became known as the bulkhead method and was subsequently developed by Halsted (1898 1910 1912

1920 1922) in the United States and by Fraser and Dott (1923) in this country The essentials of this method are that the closed ends of the bowel are brought together and sutured all round the proposed anastomosis The two ends of bowel

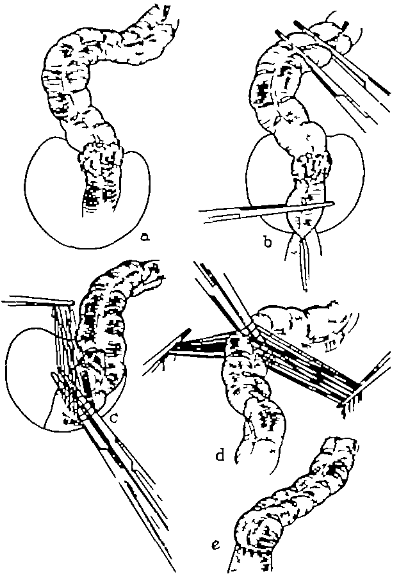

Fig 243 Two-clamp method of O Hara.

Carcinoma of lower pelvic colon.

b Two-clamp method Clamps applied for resection

c, Anterior layers inserted and held up; not yet tied

d Clamps rotated together Posterior layers inserted and held up

Sutures tied after removal of clamps. Anastomosis complete.

are then opened either by cutting the ligatures closing them with a snare or by the formidable procedure of passing a long guarded knife up the bowel from the rectum The resulting inturned flange of bowel, however is liable to cause sub-

sequent obstruction and the method is now obsolete. In his articles Halsted emphasised the importance of the submucous coat as the strongest layer of the intestine and stressed the importance of suturing it. He was also one of the first (1898) to show that a carefully sutured anastomosis of the bowel gives better results than Murphy's button or any other mechanical aid. His remarks on the subject were pointed.

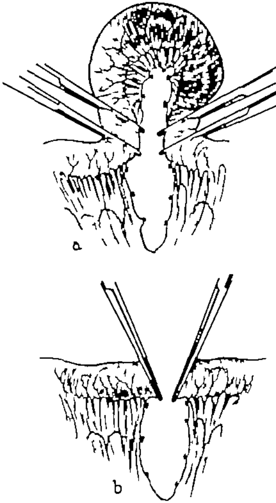

Fig. 244. Modified two-clamp method of Schoemaker and Wangensteen.

a, Method of applying the clamps.

b, Note line of section is oblique: mesentery cleared back one third of an inch.

Two-Clamp Method of O'Hara

In 1900 a New York gynaecologist, O'Hara, was experimenting on intestinal anastomosis in dogs. He found that by approximating the two cut ends of the bowel in clamps he could complete a satisfactory anastomosis over the clamps. The anterior layer he inserted first across the clamps (Fig. 243); the posterior layer was then inserted by rotating the clamps, all the stitches being tied except the last, which was tied as the clamps were removed. He states that he had found this by far the

performed with interrupted silk sutures, the posterior layer being inserted first into the adjacent margins of the bowel then the anterior layer across the closed ends of bowel (Fig 247 *c d*) A reinforcing outer layer of interrupted silk sutures is added Finally the two basting sutures are pulled out and the continuity of the bowel re-established by invagination with the finger (Fig 248)

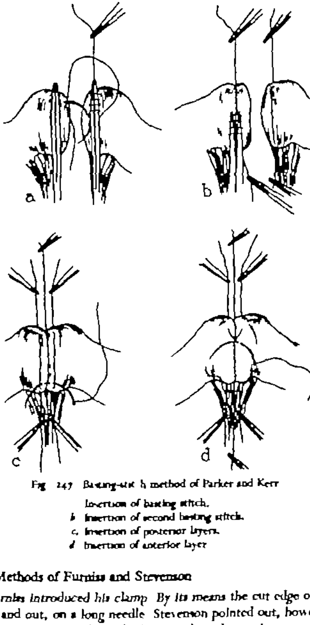

Fig 247 Basting-stitch method of Parker and Kerr
Insertion of basting stitch.
b Insertion of second basting stitch.
c, Insertion of posterior layers.
d Insertion of anterior layer

Transfixion Methods of Furniss and Stevenson

In 1934 Furniss introduced his clamp By its means the cut edge of the bowel is transfixed in and out, on a long needle Stevenson pointed out, however that this can be done quite simply without the Furniss clamp by passing a needle to and fro through the bowel below a crushing clamp Pleth first suggested transfixing the bowel with a needle for the purposes of anastomosis *in 1906 It has been recently* used in this country by Professor Pannett (1945)

One-Clamp Method of Perret and Babcock

Lastly Perret in 1927 introduced a simplification of the two-clamp method He held up the freed loop of bowel and crushed its two limbs at the desired points for section in one clamp He referred to this procedure as écrasement simultané By rotating this single clamp the posterior layers are sewn with the greatest convenience whilst the anterior layers have to be sewn across the width of one clamp only (Figs 249 and 250) Babcock (1942) is a firm adherent of this method and states that he has performed it on the oesophagus, small bowel and large bowel down as far as the rectum For the more inaccessible parts of the abdomen he uses a small clamp with detachable blades on the principle of the de Martel clamp

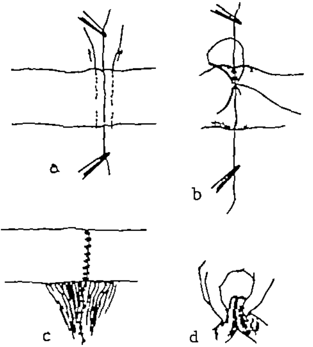

Fig 248 Basting-stitch method of Parker and Kerr (concluded).
a Removal of basting stitches.
b Reinforcing layer of interrupted sutures.
c Outer layer completed mesentery closed.
d Breaking down the crush.

COMMENT ON MODERN METHODS

Of these various methods three have stood up to the test of time

1. The basting-stitch method of Parker and Kerr and with it may be included the Furniss clamp and the needle transfixion method of Stevenson
2. The two-clamp method of O Hara Schoemaker and Wangensteen
3. The one-clamp method of Perret and later Babcock.

The *basting stitch* method is given pride of place because by its means an undoubtedly aseptic anastomosis can be accomplished In the absence of a clamp the anterior and posterior layers of sutures can be inserted immediately adjacent to

the basting stitches and the flange turned in is therefore minimal in size. The method is neat, accurate, ingenious. Its only disadvantage, and that a small one, is that the insertion of the temporary basting sutures requires a few minutes longer than the clamp methods. The writer believes that these minutes are well spent.

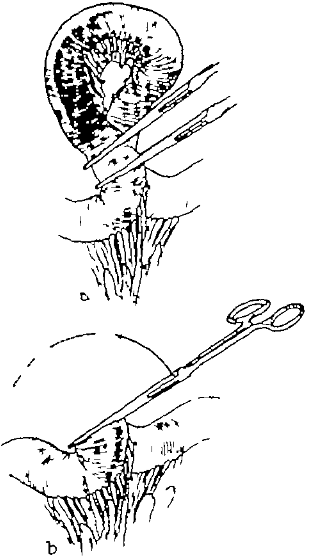

Fig. 249. One-clamp method of Perret and Babcock

a, Ecrasement [illegible]
b Rotating the clamp

The transfixion methods (Furniss and Stevenson) save these few minutes but involve passing a needle repeatedly through all coats of the bowel. The method is, therefore, not completely aseptic although the infection likely to be carried by the point of the needle is extremely small. This needle holds the bowel rigidly but its point requires control. If speed is required these methods may be useful.

The two-clamp methods of O Hara Schoemaker and Wangensteen have the great advantage of simplicity The divided ends of bowel held in fine but strong forceps are brought together and are sutured over the clamps A means of holding

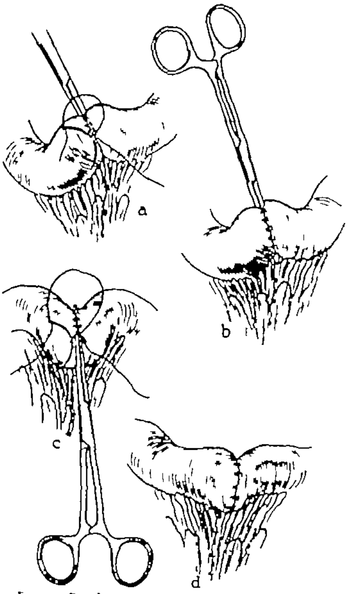

Fig 25 One-clamp method of Perret and Babcock (*concluded*)
a Insertion of posterior layers.
b Posterior layers completed.
c Insertion of anterior layer across the width of one clamp only
d Anastomosis completed.

the clamps together in the correct position is helpful (Seton Pringle 1924 Wangensteen 1941) Two methods can now be used For the insertion of the posterior layer the clamps may be rotated away from each other (Fig 245) or together

(Fig 243) For the anterior layer the sutures can be placed slightly away from the clamps and tied as they are inserted this involves the turning in of a moderate flange Alternatively the sutures are placed close to the clamps are held up firmly during the removal of the clamps and are then tied one by one The flange is thereby reduced to a minimum (Scarff 1926) Both methods are satisfactory

The one-clamp method of Perret and later Babcock requires some ingenuity in the correct application of the clamp, but this being achieved the suturing is simple (Fig 250) The posterior layers after rotation of the clamp are in direct contact and are sutured with ease whilst the anterior layers must be sutured across the width of the one clamp The inturned flange is therefore small This method is particularly useful where the portions of bowel to be anastomosed are of equal dimension its chief advantages being its simplicity in requiring the control of only one clamp and the small size of the resulting internal flange.

For the three bladed clamp method, the standard Rankin clamp available in this country is too heavy and its blades too broad Its use involves a large inturned flange A similar clamp very much reduced in size has possibilities and has given satisfactory results. With it, suturing of the posterior layers is ideal, but the anterior layers have to be brought together across the full thickness of the three blades causing a considerable turn-in. The application of the clamp outside the abdomen is easy but with limited mobility of either end of the bowel it may be difficult and clumsy

For the one and two-clamp methods a narrow but strong clamp is necessary It must not allow the bowel to slip and therefore has a longitudinal ridge on one blade and a corresponding groove on the other Its blades must meet at the point first. If not, the bowel near the tip will slip during suturing To estimate the size of the anastomosis it is marked in centimetres or inches Such clamps have been described successively by O Hara, Rostowzew Schoemaker Seton Pringle Wangensteen, Stevenson and others

POINTS OF TECHNIQUE

In all methods of aseptic anastomosis certain points of technique require special attention

1 To avoid the necessity of putting the final sutures at the mesenteric border into the mesentery itself the bowel must be cleaned of its mesentery for one third of an inch (Fig 244) This allows room for the final sutures in the bowel itself and not in the mesentery where they might endanger the blood supply of the anastomosis

2 The line of section as in any end-to-end anastomosis must be oblique more of the antimesenteric border being resected (Fig 244) This not only ensures the blood supply but also makes a larger anastomosis possible and enables one to allow for inequality in size of the two bowel ends Section of the smaller is therefore more oblique This does not apply to side-to-side anastomoses which can be equally well undertaken by these methods

3 In any of these anastomoses the points at either end of the clamps require special attention Sutures are therefore inserted at each of these two points but are tied only after removal of the clamps The turning-in and approximation at these points is thereby ensured.

4. In all aseptic anastomosis the sutures upon which the anastomosis depends must be inserted from outside the bowel. These sutures must include the submucous coat which is the strongest layer. They should therefore take a slightly deeper bite than the usual seromuscular sutures.

5. As to one or two layers. Wangensteen (1941) uses only one layer of sutures as did Wilkie (1934). In their most experienced hands this has given good results. In the writer's view the addition of an outer row of small interrupted mattress silk sutures to take weight off the anastomosis adds safety, occupies but a few minutes and adds little to the internal flange.

6. The inner layer of sutures may be continuous or interrupted. Either is satisfactory. The writer prefers the interrupted. Strength lies therein.

7. Post-operative care consists of rest and chemotherapy. If anxiety is felt about the anastomosis, rest to the bowel can be complete by the use of a Miller Abbott or Cantor tube, combined with the intravenous administration of fluids. In entirely favourable circumstances fluids are allowed by mouth until the bowels have been opened. This involves keeping the patient hungry but again adds safety. Chemotherapy consists of penicillin by injection and sulphathalidine by mouth.

ADVANTAGES AND DISADVANTAGES OF ASEPTIC METHODS

Do these methods fulfil the essential requirements of all anastomoses? Firstly that there be complete peritoneal approximation, secondly that the strong submucous coat of the bowel be sutured. Peritoneal approximation is certainly fulfilled. The suturing of the strong submucous layer is fulfilled by careful suturing, taking a slightly deeper bite than the ordinary seromuscular stitch. That the submucous layer is the strongest layer of the wall is easily shown by pulling a piece of bowel between the handles of a pair of scissors kept forcibly closed.

The advantages of the method are that if carried out meticulously by the basting stitch method, the procedure is aseptic. If done by the other methods described the soiling is minimal. With accurate suturing the method is safe and can be as quick as the open method.

Criticisms which are advanced against the aseptic technique are:

1. Haemostasis may be incomplete. For the stomach this is, in my view, an insuperable objection. Primary haemorrhage can be controlled by the cautery but the possibility of secondary haemorrhage after some days is a critical failing. For small or large bowel the author has yet to see haemorrhage cause trouble.

2. That the method is not completely aseptic. An anastomosis carefully executed by the basting-stitch method can be completely aseptic. For the other methods infection is minimal and is certainly much less than in the open method.

3. That the inturned flange may subsequently produce obstruction. In the obsolete bulkhead method this is true. In the other methods the inturned flange is small and has been shown by Scarff (1926) to disappear in three weeks.

4. That a stricture may subsequently develop because mucous membrane is not approximated to mucous membrane. This criticism is unfounded because if the submucous layer is sutured the mucosae must be in close approximation, and Scarff has shown that the mucosa rapidly reforms over the internal suture line.

5. That all suturing has to be done from outside the bowel and that the layers cannot be seen. For this reason the method requires care and experience.

EVALUATION

In many conditions resection and open anastomosis of the bowel can be safely undertaken with only a small risk of infection either at the anastomosis or in the wound. In other conditions, however, even minimum soiling may have serious and possibly fatal consequences.

For the small bowel by far the commonest of these conditions is a strangulated hernia with gangrene of the bowel, particularly if the obstruction has been of some duration and the patient's general condition is poor. The over-all mortality rate for this condition is formidable. Figures as high as 6 9 per cent have been reported (L. C. C. Subcommittee, 1948). Other such conditions requiring resection of the small bowel are obstructions caused by adhesions, internal strangulations, Krohn's disease, impaction of gall-stones. In any of these the least contamination may cause an ileus which may prove fatal. A carefully executed aseptic anastomosis can prevent that contamination.

For the large bowel we know that the Mikulicz operation is safe. Its application to the right side of the colon has certain outstanding disadvantages. With present-day improved methods of applying rest to the bowel and of disinfecting its contents by means of chemotherapy, however, modern trends have all been towards one-stage resection with immediate anastomosis. In this field aseptic anastomosis is a refinement of technique which is destined to play a small but not unimportant part.

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CHAPTER 20

The Treatment of Inguinal Hernia

A K MONRO

BASSINI HALSTED ERA

THE MODERN surgery of inguinal hernia started with Bassini in 1889 At the same time Halsted in Baltimore was developing a similar operation Both obtained results far superior to anything which had preceded them. In their hands, surgery first became a practical proposition in the treatment of uncomplicated hernia Since that time no branch of surgery has been the subject of more divergent views and none has shown more clearly the fallacies of rushing into print. Methods of repair appearing sound in theory and at operation have repeatedly in the acid test of the follow-up clinic proved of little value

Halsted at first divided the internal oblique and the transversus abdominis lateral to the internal ring in order to transplant the cord laterally repairing all the layers behind the cord to the inguinal ligament, leaving the cord subcutaneous To allow the conjoint tendon and the internal oblique to be approximated to the inguinal ligament without tension he recommended a relaxation cut in the anterior rectus sheath To reinforce the repair he watched his assistant Bloodgood suture the rectus muscle down to Poupart s ligament but never approved this procedure believing that the rectus in contracting would pull away from the abnormal position He preferred himself to turn down a flap from the rectus sheath for this purpose. He showed that ligation and excision of veins from a bulky cord was followed in 20 per cent of cases by the development of a hydrocele It was therefore discarded He subsequently thought it wiser not to disturb the cord but to suture conjoint tendon and the internal oblique to the inguinal ligament *in front of* the cord the procedure usually now associated with his name and, in this country with that of Ferguson (1899)

Halsted s treatment of the subject illustrated by Max Brodel s superlative art is a model of scientific writing Such was the effect of his work that only fourteen years later (1903) he was able to state 'The majority of inguinal ruptures are now easily and quite well cured by a variety of procedures and by the average operator

Hence it is difficult for the student and the young practitioner to comprehend that it is hardly more than a decade since this variety of hernia completely baffled the efforts of the best surgeons to cure it

During the first twenty years of this century these operations were widely practised with various minor modifications Anterior and posterior repairs with catgut ribbon catgut kangaroo tendon silk or strips of external oblique were performed with or without reinforcement by the cremaster and its fascia, the rectus muscle or its sheath the external oblique aponeurosis or flaps of deep fascia from the thigh swung up either under or over Poupart s ligament whilst the Wyllys Andrews operation produced a neat posterior repair leaving the cord in a newly formed canal between the two flaps of the external oblique Other lines of thought were developing but this period may be fairly named the *Bassini Halsted era*

GALLIE ERA

In 1921 Gallie described his method of repair with fascia from the thigh which met with general if slow acceptance It involved two principles, first the use of free fascial grafts which he showed to live and to become part of the body and secondly and more importantly the recognition of the fact that the conjoint tendon and internal oblique do not remain in contact with Poupart s ligament when sewn to it owing to tension 'The sewing of the internal oblique to Poupart s ligament in this manner is a detail of the operation which in our opinion is of very little value in preventing recurrence of the hernia No greater tension is exerted on the sutures than will make them lie flat The whole idea of the operation is to fill the weak spot in the abdominal wall with what may be called a filigree of living aponeurosis (Gallie 1924) He carried his repair up to and beyond the internal ring so that the emerging cord is surrounded by a fibrous ring which will effectively prevent the development of a hernia at this point. He furthermore laid to rest all anterior repairs with the words The time spent in preventing a hernia from getting out of the inguinal canal is much better spent in preventing it from getting into it

Operating on all types of case some recurrent for the second and third time Gallie obtained extremely good results (1924) His method therefore came to be widely adopted, at first mainly for recurrences, later for cases likely to recur Until 1930 or thereafter it was not uncommon teaching in this country that any uncomplicated hernia in a patient o er the age of 45 should be treated with a truss opera tion being recommended only for fit patients below that age With Gallie s operation this age limit could be raised and more patients given the benefit of surgery

In other hands, however Gallie s operation was not entirely successful So able an exponent as Cattell (1931) reported a recurrence rate of 7 8 per cent. The repeated passage of the large needle through a possibly already traumatized inguinal ligament does nothing to improve it or to please the meticulous surgeon doubts were cast upon whether the fascia does actually live in the repair infection was not unknown and, finally the long scar in the thigh in some cases ga e trouble This was particularly brought to light in the recent war when a number of service men had to be invalided from acti e service on ac count of alleged pain in the scar in the thigh There can be no question however that the influence of Gallie s work was profound and although other methods were in use including excision of the sac

only (Hull 1913) operations of the Bassini Halsted school the silver filigree operation (McGavin 1909) silk repairs such as that of Sampson Handley (1918) and inlays of various types this stage of the surgery of hernia may not inappropri ately be termed the *Gallie era*

SILK LATTICE SCHOOL

The next landmark was Ogilvie s masterly survey of the subject (1937) which has exerted a *profound influence on the hernia surgery* of this country He recog nised three types of inguinal hernia:

1 Those in which the only abnormality is the presence of a sac
2 Those in which there is in addition some stretching of the internal ring but the muscles of the inguinal sphincter are sound
3 Large oblique and direct herniae in which the sphincter mechanism has obviously failed

He logically advised (1) removal of the sac alone (2) removal of the sac with plastic repair of the internal ring and (3) a strong lattice replacement of the inguinal mechanism with silk (No 4 Chinese Twist) inserted to be firm but not tight The operation consisted, in essentials, of Gallie s operation using silk in place of fascia For the same purpose Maingot (1941) introduced floss silk, consisting of the individual fibrils of natural silk offering a perfectly pliable framework for the sub sequent growth of fibroblasts

From this lead arose a strong and growing silk lattice school which made considerable headway amongst other methods of repair then in use The chief of these were—to mention only a few—excision of the sac, operations of the Bassini Halsted type including particularly the McArthur and Wyllys Andrews operations, Gallie s fascial suture and the muscle-slide operation ably advocated in this country by Tanner (1942) the silver filigree operation (McGavin) and patch or inlay operations of various types McVay s (1942) use of Cooper s ligament for the inguinal repair as in the Lotheissen operation and as recommended by Babcock (1927) was considered sound in giving a firm anchor for the repair and in preventing the subsequent occurrence of a femoral hernia.

The recent war lent urgency to the problem It soon became obvious that the indiscriminate use of non-absorbable sutures in war time hospitals even with full chemotherapy carried serious risks of infection The use of silk was therefore in most spheres banned Resort was made to excision of the sac catgut posterior repairs or for larger or recurrent herniae to Gallie s operation Many of the younger surgeons were therefore brought up in the fear of silk, and the silk lattice school lost ground.

During the past eleven years, Ogilvie s three types of operation have been given an extensive trial On the whole both in and out of the services it has become apparent that in adults even in the best hands the results of excision of the sac alone or combined with a plastic repair of the internal ring are disappointing Faced with such a recurrence the surgeon may well wish he had employed more radical measures whilst the patient although no doubt interested to know that his inguinal mechanism has been preserved, is much more concerned to know that he has a repair which will stand up to unrestricted activity for the rest of his life Such

operations may satisfy theoretical and aesthetic requirements but they do not provide a really strong barrier against recurrence. It has become, in the author's opinion, increasingly the view that if an inguinal region requires repair it requires the strongest repair compatible with safety.

OBSTACLES IN EVALUATION OF METHODS

In reviewing the mass of literature on the subject of hernia it appears to the author that there are two cardinal pitfalls. *The first is to assume that a new type of*

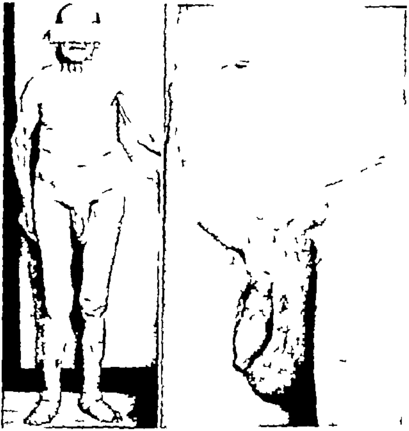

Fig. 25. L. S., aged 86. 1934, Spring truss. 1944, Bag truss. Continual attacks of inflammation since. 1948, Flow silk lattice repair. *Up at hour eighteen hours after operation. Photographs two months after operation.*

repair or of suture material will do with every surgeon what is claimed for it by its originator; the second is to think that statistics are always comparable. For the first, the originator has perfected himself in the use of his technique and has learned its pitfalls before reporting it. Only by following every detail under exactly similar circumstances can similar results be expected. For the second, it is manifestly absurd to compare sets of figures in which one concerns service cases involving only healthy men between 20 and 45 years of age, another concerns civilian cases but limited to those of sound physique, and a third which is a consecutive series in a general civilian hospital including every type of case in patients of all ages. Many surgeons

in this country now set no age limit on their cases for hernia surgery (Figs. 251 and 252) and only refuse those in which there are such definite contra indications as active phthisis severe chronic bronchitis and/or prostatic obstruction

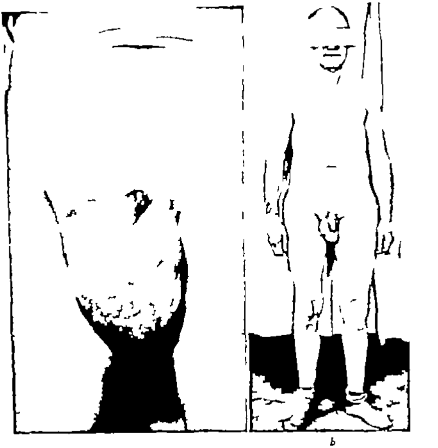

Fig. 252

J. L., aged 64. Right inguinal hernia for thirty years, reaching to bottom of scrotum. At operation, hernia proved to be *direct*. The inferior epigastric vessels were *lateral* to the neck of the sac.

b The same after operation.

METHODS IN USE TODAY

At the present time the operations in use in this country for inguinal hernia may be in the main reviewed under three headings

1. Operations of the Bassini-Halsted Type. Posterior Repairs of Various Types Using Catgut, Silk, Linen Thread, Nylon or Strips of External Oblique Aponeurosis

Typical results with these methods are those of Drinkwater (1948) who reports a 7 per cent recurrence rate for *direct* inguinal hernia in *men between 20 and 45*. Under this group also we include the muscle-slide operation of Tanner (1942). In his capable hands this has given magnificent results. In the author's view this

operation has much to commend it for the younger more muscular patient For the older patient with poor muscles which have already failed once it would appear unwise to rely on those muscles even in altered position for a repair and one has seen cases with a general bulge and weakness of the whole area resulting from this operation

On the whole these operations for *younger patients with good muscles* have given adequate results For recurrences and for patients with poor musculature they are not reliable

2. "Patch" or "Inlay" Operations

These operations have been tried but have not been extensively adopted The silver filigree operation of McGavin (1909) gave a strong repair but it had the objections of rigidity and of liability to infection Skin implants (Mair 1946) have been used. As leather they undoubtedly ha e possibilities but the presence of follicles and appendages would appear to outweigh their advantages Plastic inlays have been used with success (Thompson, 1948) whilst tantalum gauze mesh has not been extensively tried owing to difficulties of supply As described by Throckmorton (1948) it would appear to have very real advantages He calculates and cuts his gauze mesh not to the shape of the deficiency but to the position of reliable *supporting structures without tension the cord being brought out through a small* triangular opening made high on the lateral border of the implant. Subsequent exploration of such an implant showed it to be ensheathed in dense white fibrous tissue In one of his cases frank infection occurred but healing took place uneventfully in four weeks without extrusion of sutures or inlay

Inlay operations using a soft, inert material which will not perpetuate infection ha e much in their favour If of metal the results of work-hardening and of electrolytic potential must be remembered At present such operations are not extensively used in this country owing to lack of suitable material

3. "Lattice" or "Darn" Repairs with Fascia Lata, Silk, Floss Silk, Nylon, Stainless Steel Wire, or Tantalum Wire

We have seen how the silk operation evol ed from Gallie s operation avoiding the disad antages of an incision in the thigh and the necessity for using Gallie s needle *As practised by Ogilvie and Maingot the silk darn* not only fills the weak area but extends well up into the trong rectus sheath above and if necessary down to Cooper s ligament below It becomes incorporated into the tissues and stimulates the formation of a firm strong but *flexible barrier of fibrous tissue making the area as strong as the tissues* into *which the lattice extends* In the early stages of this operation the practice was to l a e the darn absolutely lax at operation Such cases were found later to show a distinct bulge on oughing and, *although symptom free and fit for* the hea iest duties, they were referred back by Service Board The lattice was therefore subsequently inserted to be *firm but not tight*

For such a repair no age limit need be set It has been *successfully* used on a number of patients over 80 years of age (Fig 251) There is no question of need for subsequent limitation of activ ties nor for a support of any kind at any age Only on the rarest occasion ha a testis been remo ed Confident in the strength of the repair we ha e erred on the ide of conservatism in this matter and have accepted as a

personal challenge to the operator the limitation of the internal ring to a size sufficient to transmit the cord and nothing but the cord. A price has been paid for this in the shape of an occasional swelling and subsequent atrophy of the testis.

Briefly, silk has many advantages. It is soft, strong, easy to sterilize, pleasant to use, absolutely flexible, non-irritant to the tissues and becomes incorporated in them to form a firm, strong, permanent barrier. Examined subsequently, it is difficult to find the silk so closely is it incorporated in the tissues. It does not cause

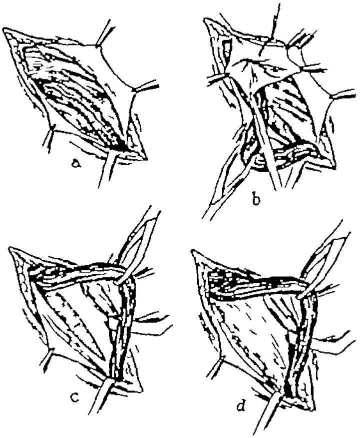

Fig. 253

Ilio-hypogastric and ilio-inguinal nerves exposed and carefully avoided.
b Removal of the sac above the neck, ligated with stout black thread.
The area t be strengthened.
d Repair of transversalis fascia

infection but if this should occur it may perpetuate it. If chemotherapy fails the silk must be removed. Before the advent of chemotherapy this proved necessary in about 1 per cent of our cases.

To avoid this risk other non-absorbable sutures are recommended. Nylon has been used with considerable success (Haxton, 1945). Moloney (1948) reports 239 inguinal darns without recurrence to date. Infection developed in 5 cases but all healed without extrusion of nylon. He has used it even in frankly infected wounds. Similarly, Abel and Hunt (1948) report 300 instances of repair with stainless steel

wire without recurrence Sinuses have occurred but have healed spontaneously On occasion small fragments of wire have worked loose and have required removal Tantalum wire reacts similarly but samples have proved too brittle to encourage further use in its present form

Of these materials nylon has the disadvantage of difficulty in making knots hold and the question of how much fibrosis it stimulates is not yet settled. Steel wire introduces a physical factor of rigidity as well as one of electrolytic activity

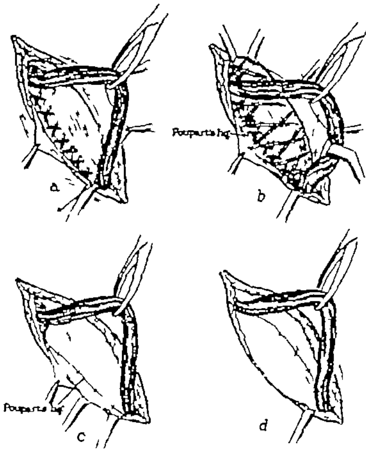

Fig 254.

a First layer of floss-like lattice Initial stitch at origin of rectus from pubic bone
b Second layer of floss-silk lattice extending out to sound tissues.
c Upper flap external oblique brought down.
d Lower flap external oblique brought up in front of upper flap

Both nylon and stainless steel wire therefore have the great advantage of not perpetuating infection Whether after general release they will continue to produce results comparable to those of their protagonists remains to be seen

Technique The 'floss silk' lattice repair here illustrated has been described previously (Maingot 1941 1948) The incision is in a crease the resulting scar therefore does not stretch and is often difficult to find. Nerves are carefully identified and avoided (Fig 253 *a*) The sac is removed *above* the neck (Fig 253 *b*) It is

always opened It is ligatured with *black* silk in order to identify the site of ligature in the event of recurrence The inferior epigastric vessels are always sought with occasional surprising results. Figure 252 shows a *direct* inguinal hernia extending into the scrotum

The repair is carried out in four layers (1) Transversalis fascia and cremaster are sutured to the deepest part of Poupart s ligament (Fig 253 *d*) (2) First layer of floss silk lattice going down to periosteum of pubis and up to push the cord out laterally (Fig 254, *a*) (3) Second or returning layer of lattice extending up into healthy rectus sheath and being continued outside the internal ring (Fig 254, *b*)

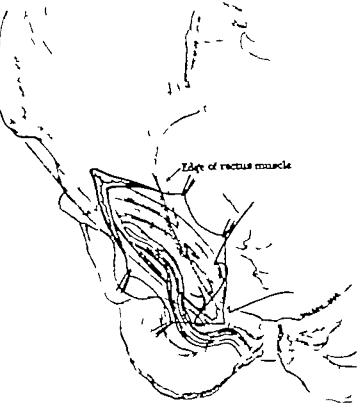

Fig 255 The inner repair sutures inserted int Cooper ligament.

(4) Double overlap of external oblique behind the cord (Fig 254, *c d*) The cord therefore now emerges directly through the muscles at the site of the internal ring which becomes fibrous and fits the cord exactly If Poupart s ligament is considered weak or a femoral hernia thought likely the inner end of the repair is taken down to Cooper s ligament (Fig 255)

An average length of floss silk used is 16 inches About double this length is sterilised by boiling Before use it is allowed to soak in penicillin solution. At no time is it immersed in any antiseptic If it is some disinfectant will remain in the silk and will act as an irritant. Serum will collect and infection will be likely

Post-operatively penicillin is given routinely in full doses and the patient is

allowed out of bed on the fourth day or earlier if of advanced years He leaves the hospital after ten days returns to light work in four to six weeks and to heavy work after three months

Conclusions From the external e operative experience of recent years, certain further facts have emerged We have learned that

a Incomplete removal of an indirect sac will be followed by a recurrent indirect hernia.
b Direct recurrence at the lower end of the scar can be prevented by taking the lowest suture down to the periosteum of the pubis
c Bulging at the site of the internal ring can be prevented by carrying the lattice out beyond the internal ring
d Too tight closure of the internal ring may cause hydrocele or swelling followed by atrophy of the testis
e Careful avoidance of nerves is essential
f Provided the repair is sound prolonged bed rest is unnecessary
g The strength of a lattice or darn repair depends not on the strength of the margins of the defect but on that of the surrounding fasciae available
h Subcutaneous transposition of the cord has no practical disadvantages

For children we are agreed on excision of the sac only For adults it is submitted that if the inguinal mechanism has failed it is wise to replace it by *a firm but flexible barrier stretching between sound fascial tissues well beyond the margins of the defect* For this purpose autogenous fascia lata proved satisfactory but its removal left a troublesome scar in the thigh Wire is a reliable substitute but introduces rigidity and has disad antages of work-hardening and subsequent fragmentation Nylon in its present form is not ideal material to work with Silk has many ad antages but requires a rigidly aseptic technique

With this method and these materials certain series of cases ha e been published showing greatly improved results Aided by advances in anaesthesia and by early ambulation age-limits ha e been largely removed and the benefits of surgery are being brought to a wider range of sufferers

For the evaluation of the various methods a careful and prolonged follow-up is essential fi e and ten year figures being necessary Any such process in this country was greatly disrupted by the war mainly by mo ement of the population As we proceed, however figures will become available again and we believe will speak for themsel es

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CHAPTER 21

Strangulated Femoral Hernia

A K MONRO

STRANGULATION of a hernia is one of the common surgical emergencies In 1946 it was responsible for 3 985 deaths in England and Wales in a total population of 43 millions Delay in reporting to a physician and subsequent delay in diagnosis are without question serious factors contributing to this mortality Every effort must be made to avoid such delays At the same time we have all seen recovery in some of the gravest cases after skillful treatment and, after a fatal case have felt that some slight difference in treatment might have altered the outcome The omission of a small point in the technique of operation, for instance in making certain that a small knuckle of gangrenous gut is firmly held whilst the constricting band is divided, may cause the patient s death Again because more than 80 per cent of strangulated external herniae do not require resection of bowel the condition is apt to be considered as commonplace and is not given the detailed consideration which the serious nature of the remaining 20 per cent demands Figures for the mortality rate of resection of bowel for this condition up to 66 per cent have been published (Jens 1943) It is estimated that the over all mortality figure is more than 30 per cent This figure is a direct challenge to all surgeons concerned

DIAGNOSIS

By definition a hernia is said to be strangulated when the blood supply of its content *interfered with* at the neck of the sac In less experienced hands there is not infrequently a tendency to try to diagnose the extent of this interference and to allow the cases showing milder symptoms to drift on with expectant measures. This cannot be too strongly condemned If a hernia is strangulated, its treatment is a surgical emergency and must be carried out forthwith

Strangulated Internal Hernia

A strangulated internal hernia is one of the rarer abdominal emergencies Its onset is usually sudden, its symptoms and general signs marked its local signs slight

The only abnormal physical signs in the abdomen may be slight distension with some generalised tenderness perhaps increased over the site of the lesion The combination of such symptoms together with pain down the inner side of the thigh to the knee (Howship-Romberg sign) and pain on movement of the hip are characteristic of a strangulated obturator hernia Such a hernia may also be felt per vaginam or possibly per rectum In other cases an exact pre-operative diagnosis is impossible Immediate surgery is indicated

Strangulated External Hernia

Of the strangulated external herniae the inguinal umbilical and incisional have certain individual characteristics Of these it is proposed to say only that the diagnosis of obstruction or incarceration in a para-umbilical hernia is a dangerous one Time is often wasted in such cases before operation is undertaken and the true diagnosis of strangulation is revealed.

Strangulated Femoral Hernia

Strangulation of a femoral hernia is in my experience the commonest strangulation. Its diagnosis is usually straightforward, the patient pointing to the responsible lesion In certain cases, however diagnosis is by no means simple

History and Physical Signs The history may be vague perhaps of nausea and slight abdominal pain only The general signs may be minimal the tongue may be clean the temperature and pulse rate normal and the signs of dehydration absent Unless extreme care is now taken to examine the hernial orifices a small femoral hernia in a stout patient is easily overlooked. Even with the greatest care in the presence of palpable inguinal glands the diagnosis may still be obscure A tense tender lump which has lost its expansile impulse on coughing should be present Tenseness is always present but tenderness is by no means so constant. In a number of cases seen by me the patient has absolutely denied tenderness in the lump and in one instance the patient a stout woman of 56 was unaware of a lump the size of a small plum in her groin The interne who was responsible for this case made the remark It cannot be a strangulated hernia because it is not tender In fact, gangrenous ileum in the sac required resection It is submitted that tenderness is by no means a reliable sign in the diagnosis of strangulated external hernia

In the case of a femoral hernia showing these physical signs any attempt at reduction by taxis is absolutely contra-indicated Even gentle pressure may rupture a gangrenous constriction ring against the sharp unyielding margin of Gimbernat s ligament, whilst to attempt to return to the abdominal cavity the contents of any strangulated hernia of more than four to six hours duration with its possible infection is dangerous In looking through old notes of such cases it is not infrequently recorded that the lump is irreducible, showing that reduction has been attempted

The Difficult Case That the diagnosis of strangulated femoral hernia is not always straightforward is shown by the case of a stout woman, 80 years of age who was admitted to the medical wards giving a five-day history of colicky pain across the lower epigastrium with vomiting The only abnormal physical sign was slight central abdominal distension rectal examination was negative An enema produced a good result with considerable relief A straight x ray of the abdomen showed dilatation of the stomach together with some distension of the small intestine The

stomach was therefore decompressed and intravenous fluids started. After removal of the gastric tube on the third day however vomiting recurred the case was therefore referred for surgery At operation through a paramedian incision, the condition was traced to a small strangulated femoral hernia of the Richter type Resection was performed but the patient died on the eighth post-operative day from congestive heart failure and broncho-pneumonia

X ray Examination In the straightforward case the diagnosis is made on the history and physical signs alone For the difficult case adjuvants in diagnosis are few Blood examination is not helpful The two-enema test so useful in lesions of the colon is of little value firstly because it is small intestine which is involved and secondly because only a part of the circumference of the bowel may be involved, as in a Richter s hernia Straight x ray films of the abdomen are thus in fact the only added investigations of help The erect film may show fluid levels in the small intestine In the stout patient in this position however the protuberant abdomen hangs over the groins and tends to obscure the areas in question The horizontal film may be of much more value. Gas in the bowel involved in the hernia may be seen below Poupart s ligament or a distended loop of small bowel may be seen leading directly to the hernial site and there disappearing X-rays may therefore give positive evidence of the condition

The old teaching can thus not be too strongly emphasised that in the examination of any case suspected of intestinal obstruction the most important point is *the examination of the hernial orifices* It would appear further that in these cases (1) the general signs are late in onset and are of little help in diagnosis (2) the local signs are of paramount importance particularly the absence of an expansile impulse on coughing, whilst tenderness is by no means always present and (3) any attempt at reduction by taxis is culpable.

Abdominal Exploration If after a full examination has been carried out the diagnosis is still in doubt it is wiser to explore the abdomen. Such procedure may occasionally show no surgical cause for the condition but it is the only means by which an otherwise undiagnosable small strangulated femoral hernia, strangulated internal hernia gall-stone obstruction, obstruction by bands and adhesions and other such conditions can be dealt with in the early stages Delay may be fatal

TREATMENT OF STRANGULATED FEMORAL HERNIA

In approximately 80 per cent of strangulated femoral herniae resection of bowel is not necessary Such cases can be treated satisfactorily by any of the three methods of approach described later In such cases the risks of infection are slight and in those of advancing years the greatest risks the patient runs are those arising from enforced immobilisation In such cases a strong repair allows early mobilisation with safety whilst the addition of an abdominal incision tends to retard it The following outline of treatment refers particularly to the remaining 20 per cent in whom resection of bowel is necessary

PRE-OPERATIVE TREATMENT

This is of the utmost importance Firstly an injection of morphine or omnopon does much to relieve the patient s anxiety Bitter experience has taught us the necessity for *gastric or intestinal decompression* in every case Suction is therefore

always employed immediately and is maintained until active bowel sounds have returned after operation. An *intravenous* drip is started into a vein in the middle of the forearm with the tubing firmly strapped to the forearm and wrist so that movement is in no way limited. The patient can move his arm and hand freely. The extent of his fluid and salt deficit is estimated and fluids are given accordingly. Attention is given to the mouth which is dry and may easily become inflamed especially in the presence of infected teeth or gums.

THE OPERATION

Anaesthesia

Local anaesthesia is satisfactory for the majority of cases and bowel resection may be carried out under it. For cases requiring resection, however, it is not ideal either for patient or surgeon. Spinal anaesthesia gives excellent relaxation, but for cases in poor condition, especially in the presence of a low blood pressure, its use is perhaps unwise. For such cases skillfully administered cyclopropane or gas-oxygen-curare is more satisfactory. Gastric suction is maintained throughout.

Surgical Approaches

There are in this country three schools of thought in regard to the treatment of femoral hernia. They advocate:

1. *The lower approach* from the thigh, below Poupart's ligament.
2. *The upper or inguinal approach.*
3. *The abdominal extraperitoneal approach* through a midline or paramedian incision.

1 The Lower Approach

The lower approach is associated in England with the name of Lockwood (1889) and has much in its favour in non-strangulated cases. In cases of strangulation it has the advantages of simplicity and directness of approach in straightforward cases, as well as its avoidance of damage to the inguinal mechanism. This however does not avoid the possibility of subsequent inguinal hernia (Butters, 1948). Its disadvantages are the danger of haemorrhage from an abnormal obturator artery in dividing Gimbernat's ligament from below, and the difficulty and dangers of inspecting the bowel and of performing an anastomosis below Poupart's ligament. Pulling down the bowel for inspection after division of the constricting band, performing an anastomosis on insufficiently mobilised bowel below Poupart's ligament, and returning the bowel through the small aperture available have each caused tragedies avoidable by other methods.

For cases in which resection is necessary, this approach thus has considerable disadvantages. For the simpler cases, the repair of Poupart's ligament to the pectineus fascia is sound in theory but in fact this fascia offers only the poorest support possible. In the post mortem room it is diaphanous and a needle cuts through it with the greatest of ease. Certain writers have referred to the possibility of placing sutures in Cooper's ligament from this approach. This is often impossible. The repair effected therefore by this approach is not strong, and is not such as to give confidence in getting the patient out of bed on the evening of operation. In a recent series Butters (1948) reports a recurrence rate of 3.3 per cent of femoral

hernia as well as a subsequent occurrence of inguinal hernia in 7 per cent by this method in spite of not touching the inguinal mechanism *Ten per cent of the cases were thus left with a hernia on the same side* The repair is therefore not strong and is by no means free from recurrences

2. The Upper or Inguinal Approach

This was first described by Annandale (1875) is usually ascribed to Lothelsen (1898) and is the most commonly used method of approach in this country at the present time Salient points in the operation are that by retraction of the lower skin *flap the hernial sac is immediately opened and its fluid mopped up* The content of the sac is then firmly held by the assistant with the aid of a moist swab and *under no circumstances* is it allowed to disappear into the abdomen The external oblique is then opened above *Poupart s ligament* and, *by pushing back the transversalis fascia,* the neck of the sac is defined from above The pubic branch of the inferior epigastric vessels often interferes and requires ligation A hernia director is then introduced on the inner side of the neck, either from above or from below and Gimbernat s ligament and the neck of the sac are divided directly medially with a hernia knife An abnormal obturator artery is seen before division; it therefore presents no difficulty Throughout this procedure the assistant has held the sac content firmly The peritoneum above the neck of the sac is now incised sufficiently to admit three fingers and the strangulated sac content is reduced into a moist swab held by them It is thus easily brought out for inspection and further treatment above Poupart s ligament

For the difficult case in which a small knuckle of bowel is gangrenous and tightly strangulated by Gimbernat s ligament where for instance it is impossible to hold the bowel owing to its tenseness or difficulty is encountered in passing the hernia director the wise procedure is to reflect Poupart s ligament dividing it as close as possible to the pubic spine (Hey Groves, 1922) By this means a technically difficult operation is transformed into a simple one and risks are much diminished The sac and its content are lifted out without further manipulation and without risk of contaminating the peritoneal cavity and can be dealt with in safety

Several methods of repair are possible The most widely used is the repair by interrupted sutures which take in successively conjoint tendon transversalis fascia, Cooper s ligament, and Poupart s ligament In placing these sutures no bite is ever taken in Cooper s ligament without the left index finger protecting the external iliac ein The finger may be pricked but not the vein This method of repair was designed to repair both inguinal and femoral canals recognising the possibility of subsequent inguinal herniation. Unfortunately it introduces a considerable element of tension, particularly in the more lateral sutures and as Gallie pointed out the conjoint tendon pulls back by a process of pressure atrophy to its original situation, leaving a thin layer of fibrous tissue

To avoid this tension the femoral ring may be closed simply by suturing Poupart s to Cooper s ligament, or by applying a patch of external oblique aponeurosis (Kidd 1948) of skin (Webb-Jones 1949) or of any suitable material The transversalis fascia is then carefully repaired and is reinforced by a lattice repair between the conjoint tendon and Poupart s ligament in order to forestall the occurrence of an inguinal hernia Because of the likely presence of infection the use of non-absorbable

sutures has always been fraught with the danger of persistent infection and sinus formation For this reason catgut has commonly been the material of choice for these repairs More recently it has been claimed that stainless steel wire tantalum wire and nylon can be safely used in the presence of infection Whether this assertion will prove true after their general adoption remains to be seen As an alternative to catgut they have much in their favour

The upper approach has therefore these *advantages*

(a) The abnormal obturator artery in the dangerous position is approached under direct vision and is easily dealt with
(b) The constricting band and the neck of the sac may be divided from both above and below
(c) The bowel can be freely and safely brought out for inspection and, if necessary resection
(d) The operation is limited to the inguinal region does not involve the addition of a major abdominal incision and carries a minimal chance of infecting the general peritoneal cavity

Its *disadvantage* is the necessary division of the transversalis fascia and the subsequent risk of inguinal herniation.

3 The Abdominal Approach

The abdominal approach to a strangulated femoral hernia has been known to all surgeons who have opened the abdomen for this condition under a mistaken diagnosis Cheatle (1921) and Henry (1936) pointed out the excellent exposure of a femoral hernia possible by an extraperitoneal approach from the abdomen. From a lower midline or paramedian incision the peritoneum is swept back from the abdominal wall until the funnel of peritoneum passing into the femoral sac is seen The peritoneum is then opened transversely immediately above the neck of the sac and the distended proximal and the collapsed distal loops of bowel are seen entering the hernia The rest of the intestines are carefully packed off and swabs are placed to mop up any fluid which may escape from the sac Gimbernat s ligament and the neck of the sac are then divided with hernia director and knife from above the fluid from the sac is swabbed away and the strangulated bowel is reduced into a moist swab and brought out through the abdominal incision Resection of the bowel can then be carried out under ideal conditions Removal of the infected sac from above however may be by no means easy and involves finger dissection at the bottom of a deep infected cavity

This approach undoubtedly gives optimum conditions for resection of gangrenous bowel as well as permitting an excellent repair by suture of Poupart s to Cooper s ligaments from within the abdomen without disturbing the inguinal region Its *disadvantages* however lie in (a) the use of a vertical lower abdominal incision thereby opening up large tissue spaces to infection with risks of immediate increased toxaemia and of subsequent incisional hernia (b) allowing infected fluid from the sac into the peritoneal cavity and (c) difficulty in removing the sac from above A ut inflammations of the peritoneum of the abdominal wall and of the incision are not unlikely and even gas gangrene has occurred. The author believes these disadvantages to be overwhelming

hernia as well as a subsequent occurrence of inguinal hernia in 7 per cent by this method, in spite of not touching the inguinal mechanism Ten per cent of the cases were thus left with a hernia on the same side The repair is therefore not strong and is by no means free from recurrences

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(c) The bowel can be freely and safely brought out for inspection and, if necessary, resection.

(d) The operation is limited to the inguinal region, does not involve the addition of a major abdominal incision and carries a minimal chance of infecting the general peritoneal cavity.

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This approach undoubtedly gives optimum conditions for resection of gangrenous bowel, as well as permitting an excellent repair by suture of Poupart's to Cooper's ligaments from within the abdomen without disturbing the inguinal region. Its *disadvantages* however lie in (a) the use of a vertical lower abdominal incision thereby opening up large tissue spaces to infection, with risks of immediate increased toxaemia and of subsequent incisional hernia; (b) allowing infected fluid from the sac into the peritoneal cavity; and (c) difficulty in removing the sac from above. Acute inflammations of the peritoneum, of the abdominal wall, and of the incision are not unlikely, and even gas gangrene has occurred. The author believes these disadvantages to be overwhelming.

With any of these approaches the involved bowel is brought out for inspection, particular attention being paid to the constriction rings, the points at which the entering and returning loops were held by the constricting band. The bowel may be (a) viable, (b) non-viable or (c) doubtful. If viable it is returned to the abdomen, the peritoneum is closed and the repair is undertaken. If non-viable, resection is required. If doubtful, the bowel is wrapt in a moist swab for five minutes. If at the end of this time its viability is still in doubt, it is considered to be non-viable and resection is undertaken as in (b). If a patch of bowel, particularly at one of the constriction rings, is gangrenous, it can be oversewn. If in doubt it is wiser to resect and so avoid subsequent stricture formation and adhesions (Barry, 1942). For this reason the injection of fluorescein and other aids in the evaluation of the blood supply of the affected loop are not considered to be of great value.

For the resection, the bowel proximal to the hernia is distended and possibly unhealthy. It is therefore resected widely, some 8 inches or more being removed. The distal bowel is collapsed but healthy. It is therefore sufficient to remove about 2 inches of it.

The Anastomosis

Open Method. The anastomosis must above all things be sound. It should also involve as little soiling of the peritoneal surfaces of the bowel as possible. For the young surgeon, a side-to-side open anastomosis gives the greatest margin of safety for the following reasons. Firstly, the sutures are inserted with the coats of the bowel in full view. Secondly, by prolonging the outer seromuscular suture for at least ½ inch beyond each end of the actual anastomosis, thereby holding the two loops in contact well beyond the anastomosis, safety is increased. Thirdly, an outer layer of a few interrupted, non-absorbable sutures is an added safeguard which takes all weight from the continuous layers when the bowel is returned to the abdomen. Fourthly, these added safety measures do not limit the size of the anastomosis which can be made of any size. In the end-to-end type of anastomosis, such safety measures turn in an increasing flange which diminishes the size of the actual functioning anastomosis, whilst the final seromuscular sutures at the mesenteric border may puncture blood vessels with possible haematoma formation and risk to the blood supply of the anastomosis.

Aseptic Anastomosis. However careful the technique used in either of these open methods, there is inevitably some degree of soiling of the peritoneal coats with the virulent bacteria contained in obstructed bowel. In the otherwise healthy patient such soiling is of slight consequence and does nothing more than to increase the adhesions between the two loops of intestine. In the type of case, however, about which we are particularly concerned, namely in the old lady with perhaps chronic bronchitis whose hernia has been strangulated for several days, the slightest soiling falls on fruitful ground and may result in infection which will swing the scales against the patient.

For the more experienced surgeon an aseptic anastomosis entirely rules out this infection. By one of the techniques described elsewhere in this volume, the two portions of bowel are brought together and are sutured before being opened. In this method all sutures are inserted from outside the bowel and must include the strong submucous layer. They therefore take a slightly deeper bite than the ordinary

seromuscular sutures and must be studied first in the cadaver By this means a safe neat anastomosis can be performed *without risk of infection*

Evaluation

In the last 109 cases of strangulated femoral hernia treated at the Southend General Hospital there were 8 deaths (mortality 7 3 per cent) Of these 109 patients, 21 required resection with 5 deaths (mortality 23 8 per cent) The ages of the 5 patients who died were 90 81 80 72 and 56 years; the duration of the strangulations were respecti ely 12 hours 5 days 8 days (Richter s hernia) 72 hours and 48 hours The causes of death were in three cases chest complications and in two cases infections with faecal fistulae

From these figures it is obvious that the patients likely to die are those of advancing years in whom treatment has been for one cause or another delayed. In such cases an apparently small factor may tip the scales between life and death It is more than ever important therefore in such cases to do everything possible to avoid infection to make a sound anastomosis and to carry out a repair which will allow the patient to be immediately mobilised These criteria are best fulfilled by

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3 Allowing *nothing* from the sac to enter the abdomen In this respect for difficult cases, the division of Poupart s ligament is a valuable manoeuvre It is transected in immediate relation to the pubic spine It is repaired by suture to the ilio-pectineal line (Cooper s ligament) immediat ly lateral to the pubic spine I have yet to see trouble arise from this procedure and have derived the greatest help from it. By its means the content of the sac is lifted out, away from the peri toneal cavity and none of its infected content has a chance of con eying infection into the peritoneum

4 An aseptic technique for the anastomosis, by which none of the highly infective bacteria of the obstructed bowel are allowed into contact with the peritoneal coats.

5 A strong repair which allows early mobilisation In this respect it is admitted that if no repair at all is done for a femoral hernia only the sac being adequately removed the percentage of recurrences would probably be small It is maintained however that a sound repair particularly with non-absorbable material which will remain in situ will greatly reduce that percentage Recognising the likelihood of subsequent inguinal herniation both direct and indirect it is wise to forestall this by a careful repair of the transversalis fascia and by an inguinal darn If the claims made that certain types of wire and nylon can be used with safety in infected cases are substantiated this is a field in which they may well prove of value

CONCLUSION

Strangulation of a femoral hernia is a condition involving an over all mortality of some 10 per cent. In those cases not requiring resection of intestine, the mortality

With any of these approaches, the involved bowel is brought out for inspection, particular attention being paid to the constriction rings, the points at which the entering and returning loops were held by the constricting band. The bowel may be (a) viable, (b) non-viable, or (c) doubtful. If viable, it is returned to the abdomen, the peritoneum is closed and the repair is undertaken. If non-viable, resection is required. If doubtful, the bowel is wrapt in a moist swab for five minutes. If at the end of this time its viability is still in doubt, it is considered to be non-viable and resection is undertaken as in (b). If a patch of bowel, particularly at one of the constriction rings, is gangrenous, it can be oversewn. If in doubt, it is wiser to resect and so avoid subsequent stricture formation and adhesions (Barry, 1942). For this reason the injection of fluorescein and other aids in the evaluation of the blood supply of the affected loop are not considered to be of great value.

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CONCLUSION

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is small arising from causes remote from the hernia In those cases which required resection the mortality in the series quoted was 23 8 per cent almost 1 in 4 cases proving fatal Of these fatalities more than half were due to causes remote from the hernia

Gangrene of the bowel is therefore a serious complication No possible step in treatment is to be ignored which tends either to make the operation safer or to favour the patient s early mobilisation and return to full function

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CHAPTER 22

Synchronous Combined Excision for Carcinoma of the Rectum

O V LLOYD DAVIES AND C NAUNTON MORGAN

A COLOSTOMY has little place in the palliative treatment of carcinoma of the rectum except for acute obstruction. The only satisfactory method of palliation for carcinoma of the rectum is excision of the primary growth which should always be performed whenever possible owing to the distressing terminal stages

Provided the growth is locally removable secondary hepatic deposits unless very extensive lymphatic extension beyond the reach of surgery and local peritoneal spread should not bar palliative excision of the primary tumour When there are irremovable secondary deposits palliative restoration of continuity is most desirable

In the large majority of cases combined excision is best performed in one stage not only because the operative field is unimpaired by an established colostomy but also because the mortality rate is lower

POSITION OF THE PATIENT

The method of synchronous combined excision requires an approach from two different aspects the abdominal and perineal The abdomino-perineal and the perineo-abdominal methods both necessitate the turning of the patient in the former case between the abdominal and perineal phases whilst in the latter two such alterations in position are necessary

This operation is carried out in the lithotomy Trendelenburg position (Figs 256 257 and 258) so that both operative fields are available at the same time The legs are supported in special lithotomy crutches incorporating ball and socket joints which permit the thighs to be abducted and also extended on the abdomen (Lloyd Davies 1939) The sacrum is supported upon a rest or sandbag so that the perineum protrudes slightly over the end of the table thus enabling the sacro-coccygeal

articulation to be approached with ease The position gives a good exposure of both the abdomen and the perineum at one and the same time thus allowing two surgeons to work synchronously or alternatively a single surgeon will have both fields at his disposal without turning the patient.

This position makes more than ever possible the excision of large advanced and fixed neoplasms owing to easier access which increases operability (resectability) rate and when two surgeons are available much time will be saved particularly when other organs are involved and also require resection.

ANAESTHESIA

Omnopon 20 mg ($\frac{1}{3}$ grain) and scopolamine 0.4 mg ($\frac{1}{150}$ grain) is given one hour before operation Although spinal anaesthesia has been extensively used in the

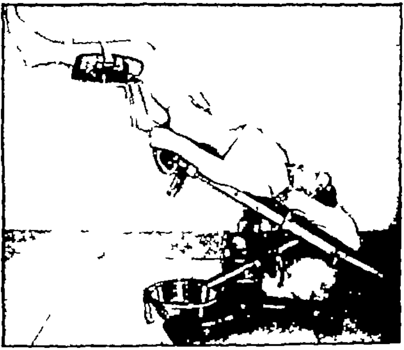

Fig 256 Lateral view of patient in lithotomy Trendelenburg position showing extension of thighs from abdomen

past, preference is now given to other forms of anaesthesia owing to the fall of blood pressure with the former

Anaesthesia is induced with pentothal followed by ether trilene or cyclopropane with oxygen.

The muscular relaxation produced by the injection of curare is equal to that produced by a spinal anaesthetic Small doses of this drug are administered throughout the operation when increased relaxation is required

An intravenous drip is always started before operation commences and is an essential part of the procedure

Immediately the patient is anaesthetised a Tiemann catheter is passed just within

the bladder which is completely emptied by manual compression above the pubes a spigot being inserted before the pressure is released in order to prevent air entering the empty bladder In the male the catheter is tied in and the penis and scrotum are strapped to the right thigh and groin

THE ABDOMINAL APPROACH

The abdomen is opened through a long left or right paramedian incision which extends to the pubis The whole of the abdominal cavity is systematically explored, and the liver omentum, and peritoneum carefully palpated for the presence of secondary deposits The whole colon is examined for an additional primary tumour which if present may alter the plan of operation

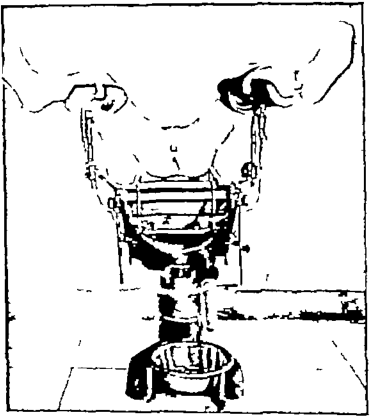

Fig 57 Perineal view showing sacral rest and accessibility Note position of coccyx marked by black triangle

The rectal growth is now examined. Its situation in relation to the pelvic peritoneal pouch its size degree of perirectal infiltration or peritoneal involvement, lymphatic spread, and attachment to other organs are noted.

Though a growth may be apparently fixed and appear at first sight to be irremovable before a final decision is made regarding inoperability a trial dissection upon its fixed aspects should be carried out. As a rule the tumour can be freed from the sacrum in such cases and only when an anterior trial dissection has revealed that the bladder base or both ureters are grossly involved should the case be deemed

inoperable This trial dissection is always advised because frequently fixity is due not to extension of the growth but to perirectal inflammation

OPERATION

The congenital adhesions on the outer side of the sigmoid loop are now carefully divided and the loop freed, thus preserving the peritoneum of the left iliac fossa (Fig 259) The peritoneum on the left side of the base of the mesosigmoid is incised as it crosses the pelvic brim and the left ureter located and isolated from the base of the mesosigmoid (Fig 260)

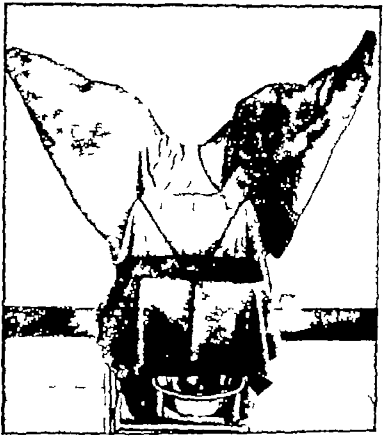

Fig 258 Perineal view with operation field isolated.

The vascular pattern in the mesosigmoid is variable and this is now reviewed to determine the place in the colon at which the terminal colostomy will be made

In about half the cases it will be found that the descending branch of the left colic artery will provide a good blood supply for the colostomy to be established in the uppermost portion of the sigmoid loop whilst in the remainder it will be necessary to retain the first sigmoid artery

The peritoneum on the right side of the base of the mesosigmoid is now incised from just below the level of the sacral promontory to the point previously selected for ligature of the main vascular pedicle This pedicle is now divided between strong ligatures

The pelvic dissection is next commenced by lifting forwards the rectosigmoid mesentery from the sacrum and inserting a pair of blunted scissors downwards and backwards along the front of the sacrum and behind the mesorectum The fingers are now introduced into the space so produced and the mesorectum deliberately separated and pushed forwards from the front of the sacrum until the whole hand can be inserted between the sacrum and mesorectum This separation is now continued to the coccyx but occasionally tough strands of pelvic fascia will require division with the scissors At this stage the abdominal and perineal dissections join behind the mesorectum and the rectum is completely free posteriorly

The hand is finally swept laterally on both sides to make prominent the lateral ligaments

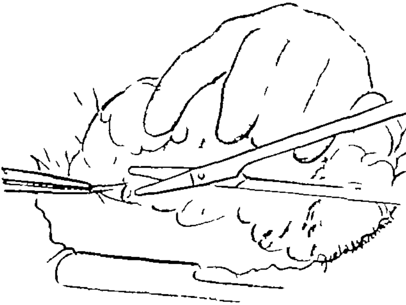

Fig 259 Mobilisation of sigmoid loop and it mesentery by division of congenital peritoneal folds on the outer side

The peritoneum and subperitoneal tissues are now incised on either side of the bowel as far down as the bottom of the peritoneal pouch

These two incisions in the peritoneum are joined anteriorly just in front of the lowest part of the pouch The base of the bladder and both vesicles or vaginal wall are now identified by dissection with blunt-nosed scissors When the vesicles come into iew they are completely defined as they extend laterally (Fig 261) In so doing the fascia of Denonvillier has been incised and now a distinct line of cleavage ex tending as far downwards as the apex of the prostate or perineal body will be found with the fingers In this space the fingers are again swept laterally to define the anterior aspects of the lateral ligaments on either side

The lateral ligaments are now alternately placed on the stretch by retraction of the rectum to the opposite side by means of the left hand and di ided (Fig 262) The middle haemorrhoidal arteries may require ligature If extrarectal spread or

inflammation at this level makes definition of the lateral ligaments difficult, the ureters must be dissected and traced throughout their pelvic course to the bladder before the ligaments are divided. At this stage the abdominal dissection is complete.

Fig 160.

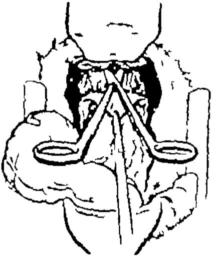

Fig 16

Fig 161

Fig 160 Division of the peritoneum on the left side of the base of the mesosigmoid with exposure of the left ureter

Fig 16 Anterior dissection showing separation of the vesicles and vasa from the anterior wall of the rectum in order to enter the line of cleavage between the prostate and rectum.

Fig 162 Division of upper portion of lateral ligament from above

A small area of skin is excised about 2 inches away from the left anterior superior iliac spine along a line between the spine and the umbilicus and a stab incision is made through the abdominal wall the sharp edges of the external oblique being divided across the direction of its aponeurosis to avoid constriction of the bowel The blades of a Parker Kerr forceps are now passed through the stab wound and the

colon clamped at the site for colostomy A small crushing clamp is placed on the colon distally and the bowel divided The covering aseptic cap is applied over the blades of the Parker Kerr forceps and bowel withdrawn through the stab wound The excised bowel is now removed through either the perineal or abdominal incision

Suture of the peritoneal pelvic floor can now easily be accomplished over the empty pelvis The edges of the peritoneum should be invaginated by a Lembert stitch the main pedicle ligature covered and suture continued outwards along the edge of the divided mesocolon towards the colostomy where the parietal peritoneum on the posterior and lateral walls of the abdomen on the outer side of the colon are brought together to close the outer space (Rankin 1927)

The abdomen is closed without drainage and the wounds sealed with Whitehead s varnish and gauze dressings applied

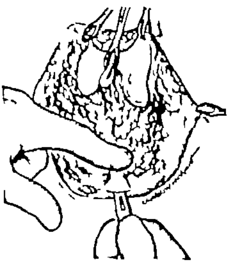

Fig 163 Removal of a portion of coccyx A coccygeal joint is sought with the point of the knife whilst upward pressure with finger of the other hand is exerted at the tip of the coccyx

The mesentery is ligated immediately proximal to the clamp holding the colon, a glass rod then inserted through the mesocolon proximal to this ligature to prevent retraction of the bowel and the clamp removed

PERINEAL APPROACH

The anus is closed with a subcutaneous purse string suture of stout silk and the operative field prepared and isolated

The perineal dissection is only commenced after the abdominal surgeon has explored the abdomen assessed the operability of the growth and the method of its eradication

A transverse incision 1 to 2 inches in length is made in front of the anus Further incisions are extended backwards from its extremities through the skin overlying the ischio-rectal fossa on either side of the anus to meet over the sacro-coccygeal articulation

These incisions are deepened through the finely granular fat of the perianal space

until the avascular lobulated fat of the ischio-rectal space is seen and the coccyx exposed

A portion of the coccyx is now excised This is facilitated by flexion of the coccyx in order to open up a coccygeal joint into which the point of the knife is inserted (Fig 263)

The knife should be kept close to the superior surface of the bone The dense fascia of Waldeyer will now be seen lying on the bed of the excised coccyx.

Small lateral incisions are now made on either side of the divided coccyx through the fibrous attachment of the coccygeus muscles

This enables the finger to be inserted on each side to separate the ilio-coccygeus muscles from underlying fascia of Waldeyer

In this plane the index finger passes forwards and outwards and re-enters the ischio-rectal space between the anterior border of the ilio-coccygeus and the

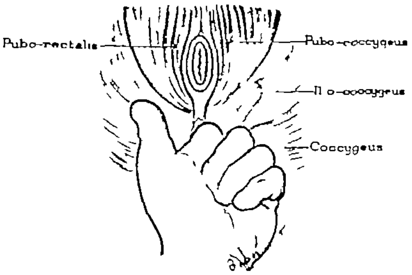

Fig 264. Diagrammatic representation of the finger being inserted upwards and outwards above the coccygeus and ilio-coccygeus muscles.

superior border of the pubo-coccygeus (Fig 264) The ilio-coccygeus muscles and overlying structures are now divided on either side with blunt-nosed scissors (Fig 265) The inferior haemorrhoidal vessels will require ligature

A self retaining St Mark s perineal retractor is placed in position and the fascia of Waldeyer incised just in front of the divided coccyx and where the mesorectal fat will be seen to protrude (Fig 266) The middle sacral vessels will have been divided and require ligature The fascia of Waldeyer is divided laterally at the level of the bony pelvic outlet and the fingers now can safely separate the mesorectum from the front and sides of the bony pelvis as far as the level of the sacral promontory in an average sized pelvis At this stage the two operators meet behind the mesorectum on the front of the sacrum

Traction is now made on tissue forceps holding the divided perineal skin The transverse perineal muscles are sought on either side and the plane of di section

kept closely behind these muscles to avoid injury to the urethra. In the middle line the decussating fibres of the external sphincter muscles are divided as they pass forwards to the central point of the perineum until the whole extent of the transverse perineal muscles is exposed. The white glistening fibres of the longitudinal muscle of the anterior rectal wall will now be seen.

At this stage inspection of the lateral aspects of the rectum will reveal the broad strap-like pubo-coccygeus muscles as they pass backwards from their origins closely embracing the sides of the rectum and prostate.

A finger is inserted above the superior border of each muscle and it will be found that the greater part can be separated from the lateral rectal wall (Fig. 267). The muscles are divided on either side and the underlying ensheathing layers of visceral pelvic fascia will be seen covering the bowel.

Fig. 265

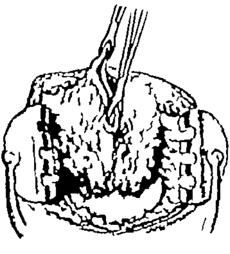

Fig. 266

Fig. 265. Division of separated coccygeus and ilio-coccygeus together with fat of the ischio-rectal space.

Fig. 266. Perineal retractor in situ—fascia of Waldeyer. Following division of the coccygeus and ilio-coccygeus on both sides, the fascia of Waldeyer is exposed.

The lateral aspects of the prostate are now easily palpated and the plane of the posterior aspect of the gland and the position of its apex assessed.

The thick inferior borders of the pubo-coccygeus (pubo-rectalis) are still undivided and firmly hold the ano-rectal junction forwards in the middle line. The borders of these muscles together with a sheet of longitudinal muscle fibres of the rectum passing forwards from the bowel to the back of the membranous urethra and apex of the prostate (recto-urethralis muscle) form a tough fibromuscular barrier between the superior aspect of the transverse perineal muscles and the posterior aspect of the prostate. This fibromuscular barrier may be separated into two portions in the middle line by blunt dissection with an artery forceps which is directed towards the apex of the prostate parallel to the plane of the posterior aspect of this gland which can at the same time be located by palpation between the finger and thumb of the hand (Fig. 268).

The two fibromuscular bundles thus produced are each divided to the back of the greyish-white fibrous capsule of the prostate

Here the plane of cleavage becomes quite distinct The visceral pelvic fascia holding the lateral aspect of the prostate to the rectum on each side is now divided and the two organs completely separated Vessels lying in the fascia on each side usually require ligation. The junction between the abdominal and perineal dissection is now reached anteriorly

All that remains to free the rectum completely is division of stout lower portions of the lateral ligaments if these have not already been divided from the abdomen (Fig 269)

If the rectum is to be delivered upwards into the abdomen, the perianal skin and anal canal are enclosed within a glove and handed through the pelvis to the

Fig 267

Fig 268

Fig 267 Separation of pubo-coccygeus from lateral aspect of rectum and division with blunt-nosed scissors, commencing from the superior edge of the muscle

Fig 268. A retractor holding forward the transverse perineal muscles. Separation of the inferior portions of the pubo-coccygei (the pubo-rectalis) in the midline anteriorly A pair of artery forceps is passed towards the posterior aspect and apex of the prostate

abdominal operator Haemostasis is secured and to avoid the risk of reactionary haemorrhage it is important at this stage that the blood pressure should be approximate to the patient's normal

The perineal skin is sutured with everting mattress sutures a corrugated rubber drain being inserted through the centre of the sutured wound alternatively a rubber bag packed with gauze may be used when the peritoneal floor is thin and requires support.

In the female the dissection is similar but when a portion of the growth lies anteriorly in apposition to the vagina the whole posterior vaginal wall should be removed with the rectum No attempt at reconstruction of the vagina is made but the whole of the perineal skin incision is sutured, re-forming the vaginal orifice through which the perineal wound is drained.

POST-OPERATIVE TREATMENT

The intravenous drip is continued after the operation until normal peristalsis returns and flatus is being passed through the colostomy this usually occurs forty eight to sixty hours after the operation During this time fluid by mouth is withheld and the dangers of acute dilatation of the stomach and paralytic ileus are considerably diminished.

An Officer double drip chamber is used with the drip apparatus and a transfusion of 500 c c of blood is started during the operation and a further blood transfusion given afterwards if necessary Normal saline is given in the drip until the urinary chloride output returns to normal and thereafter an isotonic solution of 0 18 per cent saline and 4 3 per cent glucose in pyrogen free water is given at the rate of

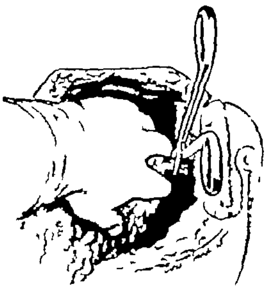

Fig 169 Division of the lower portion of lateral ligament from the peritoneum.

3 litres every twenty four hours This gives the patient a sufficient quantity of salt and water

The urinary chlorides are tested twice daily and a diminution in the amount excreted may indicate the onset of ileus During this period frequent warm mouth washes are given to encourage the flow of saliva and if the fluid balance is satisfactory the sensation of thirst will disappear within twenty-four hours The patient is returned to bed lying flat or with the foot of the bed raised on low blocks for the first six to twelve hours After this interval the patient is gradually raised on pillows and frequently moved from hip to hip to prevent a pressure necrosis of the perineal skin. The perineal drain is removed in forty-eight hours and the wound gently irrigated with a solution of Milton* (1 part in 40 parts water) In cases in which a rubber bag and packing have been necessary half the pack is removed in

Solution of Milton Sodium hypochlorite c.c sodium chloride 6 5 c.c. water to make 100 c.c

forty-eight hours and the remainder of the pack and the bag on the third day The perineal wound is now irrigated twice daily and a corner of gauze soaked in the Milton solution is inserted into the opening to prevent closure of the skin until the main cavity has healed

The abdominal and perineal skin sutures are removed on the fifth day and the abdominal wound re-sealed with a Whitehead s varnish dressing The protruding colon is trimmed to within 1 inch of the abdominal wall on the seventh day

In males the indwelling catheter is attached to a Dukes apparatus which incorporates an antiseptic seal and enables the bladder to be emptied every four hours and irrigated twice daily without disturbance to the patient The catheter is removed on the third or fourth day and thereafter the patient is carefully observed to ensure that bladder emptying is complete Females are catheterised every eight hours.

Regular deep breathing exercises are instituted and early ambulation is encouraged.

SYNCHRONOUS COMBINED EXCISION [PERSONAL SERIES OF BOTH AUTHORS, 1939-48]

Out of a total of 361 cases of carcinoma of the rectum 317 cases (87 8 per cent) were treated by the synchronous combined excision method of resection and in many instances other involved organs were removed at the same time There were 26 deaths (mortality 7 2 per cent) The remaining cases 44 in number were considered inoperable on account of gross involvement of the liver or peritoneum by metastases or extensive pelvic spread. *These latter cases were abandoned only* after determined trial abdominal dissection

The resectability rate in the last 100 cases was 98 per cent In only two cases was the tumour regarded as non resectable and in these palliative colostomy was performed

Dukes (1932) has classified his cases into three stages according to the extent of the spread at the time of operation

Stage I (A) cases are protuberant in character and limited to the bowel wall Their incidence is approximately 15 per cent

Stage II (B) cases are ulcerated and extrarectal spread has occurred by direct continuity They are frequently fixed by inflammation Their incidence is approximately 35 per cent

Stage III (C) cases are deeply ulcerated and the lymphatic glands are involved Their incidence is approximately 50 per cent

The survival figures for combined excisions of all types at St. Mark's Hospital are given in the table below

St. Mark's Hospital Figures for All Types of Combined Excision Operations 1928–1941 Inclusive

Five Year Survival Rate (Operation Deaths Excluded)

DUKES CLASSIFICATION	NO. OF CASES		UNTRACED REGARDED AS DEAD	DIED IN LESS THAN 5 YEARS, ANY CAUSE	ALIVE AT 5 YEARS	PER CENT 5 YEAR SURVIVORS
Stage I A	46	12.6%		7	39	84.8
Stage II B	122	33.3%	1	43	78	63.9
Stage III C	198	54.1%	3	29	66	33.3
	366		4	79	183	50.0 ( )

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Rankin, F. W. (1927) *J. Am. Med. Assoc.* 89, 196

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St. Mark's Hospital Figures for All Types of Combined Excision Operations 1928–1931 Inclusive

Five Year Survival Rate (Operation Deaths Excluded)

DUKES CLASSIFICATION	NO. OF CASES		UNTRACED, REGARDED AS DEAD	DIED IN LESS THAN 5 YEARS, ANY CAUSE	ALIVE AT 5 YEARS	PER CENT 5 YEAR SURVIVORS
Stage I A	46	12.6%		7	39	84.8
Stage II B	22	33.3%		41	78	63.9
Stage III C	9	54.%	3	29	66	33.3
	366		4	79	83	5 0 (av.)

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CHAPTER 23

Radical Retropubic Surgery of the Prostate

TERENCE MILLIN

SINCE WE INTRODUCED our retropubic approach to the prostate some three and one half years ago this has established itself in the majority of the largest urological clinics in Europe as the procedure of choice in dealing with the enucleable gland The technique of retropubic adenectomy has been sufficiently described and adequately established as to require no further elucidation in these pages. The radical operations how ever available to those versed in retropubic surgery are less well known and have been the subject of numerous questionnaires addressed to us Many fallacies appear to exist as to the potentialities of the operations and several mendacious statements have crept into the literature obviously perpetrated by authors who ha e little concept of what can be achieved.

SCOPE AND INDICATIONS

We can state categorically that the whole prostate within its true capsule together with the seminal vesicles and as much of the bladder as necessary may be removed in a single bloc Should this removal jeopardise the ureteric orifices the ureters may be reimplanted higher in the remainder of the bladder or alternatively be transplanted into the pelvic colon, feats that cannot be accomplished in the perineal approach. *More important still it is easy to palpate the iliac vessels and note the* presence of affected lymph glands when dealing with malignant disease a finding which in general, would rule out radical surgery This important examination, again cannot be effected by the perineal route It is not generally appreciated how after sectioning the pubo-prostatic ligaments the membranous urethra may be drawn 2 to 3 cm into the pel is and the plane of clea age between the apex of the prostate and the rectum found with the exploring finger This is the clue to a successful and clean eradication of the prostate in toto

We ha e utilised the radical operation in varying forms to be described later for the following conditions

1 Early cases of prostatic carcinoma either with or without antecedent oestrogen therapy

2 Small malignant papillary lesions of the bladder neck where total cystectomy appeared unwarranted and transurethral resection unsuitable

3 Infective calculous prostatitis causing marked symptomatology

4 Infective prostatitis not responding to the accepted conservative methods of treatment

Some elaboration of the above mentioned indications is perhaps necessary

Carcinoma of the Prostate

We have long been at one with the consensus of urological opinion that but a small proportion of cases of prostatic carcinoma diagnosed as such on clinical examination, is amenable to surgical removal with a hopeful prospect of cure The advent of oestrogen therapy with its immediate brilliant therapeutic success would seem still further to limit the indications for radical surgery A realisation, however of the limitations of oestrogen therapy and the absence of permanent cure with its use have once again aroused an interest in the surgical attack. We ourselves have deemed only 19 out of 220 cases of prostatic malignancy seen in the two-year period 1947–1948 as warranting radical surgery but have recently embarked on a programme of total removal after preliminary oestrogen therapy in a larger proportion of cases Our experiences of the perineal approach had in such cases been none too happy and we have found the retropubic route to conform more nearly to our concept of the radical surgery required in handling malignant disease

Papillary Neoplasm of the Vesical Neck

This lesion we have in general, treated by means of transurethral resection combined with electro-coagulation of the base of the tumour and the immediate results have surpassed those we had been able to obtain by other therapeutic measures The procedure however of necessity remains palliative in most cases We have met with only 2 cases in which a limited retropubic excision appeared indicated In these we removed the supramontine portion of the prostate within its capsule the vesicles and half the bladder base Excellent results were obtained in both and one has now passed the three year mark without evidence of recurrence Both patients possess full urinary control Most of the cases of vesical neck malignancy when first seen are so advanced as to be inoperable from a curative standpoint or to call for a total cysto-prostatectomy

The conservative operation we describe would appear to have a limited but definite applicability Couvelaire of Paris has described the successful use of this technique but in his case he had perforce to sacrifice about half the bladder and reimplant the ureters higher in the viscus His patient was alive and well with full continence and no marked frequency seven months later

Calculous Prostatitis

This condition would appear to represent the main indication for the radical retropubic operation. The suprapubic transvesical operations for this condition have been on the whole unsatisfactory as have the conservative perineal procedures

and the transurethral resections in that a portion of infected and calculus-bearing prostatic tissue is inevitably left. With a full appreciation of this unsatisfactory state of affairs Henline of New York proposed his subtotal perineal technique. The choice would appear to us to lie between the perineal and the retropubic routes. We advocate the latter by virtue of its greater ease and the minimal risk of such unpleasant sequelae as incontinence, stricture and fistula formation.

Infective Prostatitis

This condition is invariably first treated conservatively with varying degrees of success. All urologists will admit, however, that too many patients are left little better symptomatically, only to develop marked neuroses not unconnected with their apparently incurable condition and not infrequently to end their days with a suicide's death. Radical surgery would appear to have a place in the treatment of the condition where conservative therapy has failed, as has been emphasised by Crabtree and Lowsley independently in America. Both these authors advocated a radical perineal ablation but we have found the retropubic operation simpler and most efficacious in the few cases in which we felt justified in proposing the intervention. The following case illustrates our point.

A medical man, aged 43, developed non-specific prostatitis accompanied by marked rheumatic manifestations and neuroses. Much conservative therapy was given without avail. A prostatic abscess developed and was drained perineally. As the symptoms persisted, another urologist performed transurethral resection. No benefit followed this procedure. One year's course of prostatic massage and urethral dilatation followed without benefit. The patient made the interesting observation that sexual intercourse, by now a most painful act, was followed by complete relief of symptoms, both local and general, for seven to ten days. The ejaculate was almost pure pus. He sought complete extirpation of prostate and vesicles. The likelihood of sexual impotence following such an operation was pointed out to him and his wife, but owing to the incapacitating nature of his disability the operation was sought regardless of such consequence. A radical retropubic removal of prostate and vesicles was carried out, with immediate relief of symptoms, local and general. The patient is now, some months later, symptom free with sterile urine.

TECHNIQUE

RADICAL SUBTOTAL PROSTATECTOMY

Applicable Chiefly to Calculous Prostatitis

A No. 5 Ch. rubber Tiemann catheter is passed and the bladder thoroughly washed out with any desired antiseptic (we employ acriflavine 1: 1000). The bladder is emptied, assisted by suprapubic pressure, and the catheter left in situ. After appropriate antisepticisation of the field of operation and towelling up, a 3 to 4 inch transverse incision is made at the level of the upper border of the pubis. The skin edges being retracted, all bleeding points are coagulated. The anterior sheath of the rectus is now incised transversely one fingerbreadth above the pubis; the outer extremities of the incision are prolonged upwards and outwards so that a bucket-handle type of aponeurotic flap may be turned upwards after being freed from the underlying pyramidales and recti muscles. The inferior flap of the aponeurosis is now incised downwards in the middle line to the upper border of the pubis. The pyramidales and recti are separated in the midline and our self-retaining retractor is introduced. (This is now our standard approach in all retropubic operations.

adequate exposure is obtained and a solid abdominal wall secured with a concealed scar) A folded swab is then laid on the bladder before introducing the upper blade of the retractor This prevents the bladder from extruding itself downwards into the field and gi es extra depres ion of the viscus

The next step is to clear the anterior surface of the prostate and so bring into clear relief the true capsule with its coursing plexus of eins In most cases a pancake of fatty tissue will be seen overlying the prostate in which will lie some friable veins of variable size These veins are carefully sought and divided between haemostats they are then coagulated The fatty tissue is gently teased from the middle line outwards with long dissecting forceps This step requires care as accidental tearing of unsuspected veins leads to troublesome bleeding which will militate against clear exposure

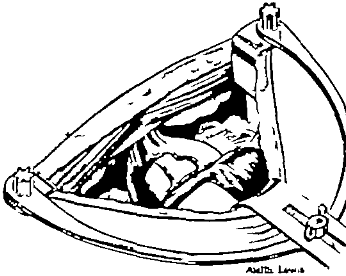

Fig 270 Exposure of the prostate showing the pubo-prostatic ligaments.

The anterior surface of the prostate ha ing been freed and the pubo-prostatic ligaments exposed (Fig 270), the next step is to seize these latter structures on ach side with long curved Kocher forceps and di ide them with scissors The forceps are removed after being touched with the coagulating current. The right index finger is now passed along the right lateral surface of the prostate and the apex felt for in contact with the upper leaf of the urogenital diaphragm. With the thumb and third finger utilised to draw the prostate upwards into the pelvis the index finger readily detects the mobilisation of the gland obtained in this manoeuvre and the palpable length of membranous urethra (with its contained catheter) now within the bony pel is *Gentle pressure with the index finger below* the urethra will identify the plane of clea age between this structure and the underlying rectum protected by the dense fascia of Denon illier

When the forefinger has been insinuated under the membranous urethra a flexible copper spatula, 1 cm wide is substituted for the finger (Fig 271) After elevation

and the transurethral resections in that a portion of infected and calculus-bearing prostatic tissue is inevitably left. With a full appreciation of this unsatisfactory state of affairs Henline of New York proposed his subtotal perineal technique The choice would appear to us to lie between the perineal and the retropubic routes. We advocate the latter by virtue of its greater ease and the minimal risk of such unpleasant sequelae as incontinence stricture and fistula formation

Infective Prostatitis

This condition is invariably first treated conservatively with varying degrees of success All urologists will admit however that too many patients are left little better symptomatically only to develop marked neuroses not unconnected with their apparently incurable condition and not infrequently to end their days with a suicide's death Radical surgery would appear to have a place in the treatment of the condition where conservative therapy has failed as has been emphasised by Crabtree and Lowsley independently in America Both these authors advocated a radical perineal ablation but we have found the retropubic operation simpler and most efficacious in the few cases in which we felt justified in proposing the intervention. The following case illustrates our point

A medical man, aged 43 developed a non-specific prostatitis accompanied by marked rheumatic manifestations and neurosis. Much conservative therapy was given without avail. A prostatic abscess developed and was drained perineally As the symptoms persisted another urologist performed a transurethral resection. No benefit followed this procedure One year course of prostatic massage and urethral dilatation followed without benefit. The patient made the interesting observation that sexual intercourse by now a most painful act, was followed by complete relief of symptoms, both local and general, for seven to ten days. The ejaculate was almost pure pus. He sought complete extirpation of prostate and vesicles. The likelihood of sexual impotence following such an operation was pointed out to him and his wife but owing to the incapacitating nature of his disability the operation was sought regardless of such consequence A radical retropubic removal of prostate and vesicles was carried out with immediate relief of symptoms, local and general The patient is now some months later symptom free with sterile urine

TECHNIQUE

RADICAL SUBTOTAL PROSTATECTOMY

Applicable Chiefly to Calculous Prostatitis

A No 15 Ch rubber Tiemann catheter is passed and the bladder thoroughly washed out with any desired antiseptic (we employ acriflavine 1 1000) The bladder is emptied assisted by suprapubic pressure and the catheter left in situ. After appropriate antisepticisation of the field of operation and towelling up a 3 to 4 inch transverse incision is made at the level of the upper border of the pubis. The skin edges being retracted all bleeding points are coagulated The anterior sheath of the rectus is now incised transversely one fingerbreadth above the pubis the outer extremities of the incision are prolonged upwards and outwards so that a bucket handle type of aponeurotic flap may be turned upwards after being freed from the underlying pyramidales and recti muscles The inferior flap of the aponeurosis is now incised downwards in the middle line to the upper border of the pubis. The pyramidales and recti are separated in the midline and our self retaining retractor is introduced (This is now our standard approach in all retropubic operations

severance of the prostate is then completed the scalpel cutting directly on to the spatula which thus protects the rectum This preservation of a distal button of prostatic tissue is desirable as it is in the perineal counterpart operation rendering subsequent reparative suturing easier and minimising the likelihood of subsequent post-operative stricture and incontinence

The proximal portion of the prostate is seized with a volsellum or other appropriate holding forceps and turned upwards and peeled off the rectum until the attachment of Denonvillier's fascia to the under surface of the vesicles is reached The fascia is incised in the midline so exposing the vesicles (Fig 273) The surgeon may then decide whether he will remove the vesicles together with the prostate or leave them in situ In general we remove them

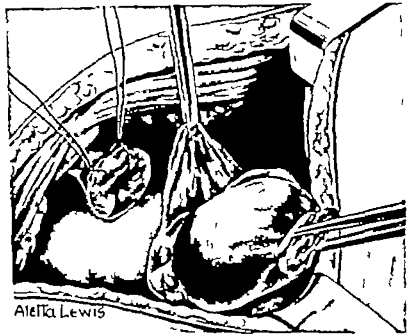

Fig 273 Exposure of the seminal vesicles after sectioning of fascia of Denonvillier (held in Allis forceps) The prostate has been freed from the rectum. The two antero-lateral stay sutures placed in distal prostatic button are shewn.

When this mobilisation has been effected, it but remains to sever the gland from the bladder neck The spatula is placed beneath the vesical outlet and the prostate allowed to drop back into its normal position The vesical outlet is then severed as shown in Fig 274, and the prostate with or without attached vesicles, removed The bladder neck is now elevated with Allis forceps and bleeding points are picked up and coagulated Careful digital palpation of the vesical outlet is now made and if there is evidence of sclerosis a wedge is cut subepithelially from the posterior lip carefully avoiding the ureteric orifices which can be clearly seen.

A two-eyed rubber Harris type of soft rubber catheter (20 Ch.) is now passed along the urethra and the distal extremity drawn temporarily upwards over the pubis until the posterior approximating suture is placed (Fig 275) Utilising the

of the spatula, gauze dissection will further free the distal portion of the prostate from the underlying rectum The anterior surface of the prostate is now incised

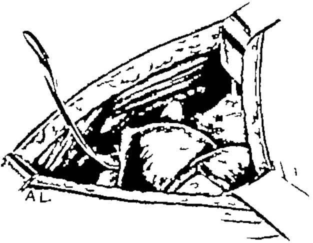

Fig 27 Spatula in position beneath apex of prostate Note mobilisation of prostate after sectioning of pubo-prostatic ligaments.

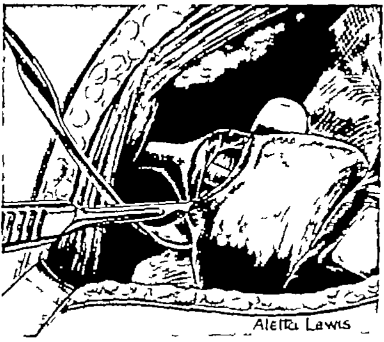

Fig 27 Distal sectioning of prostate Catheter exposed rectum protected by spatula.

transversely 0 5 to 1 cm proximal to the apex, as shown in Fig 272 until the catheter is exposed Utilising the small boomerang needle two stay sutures are placed antero-laterally in the distal button of prostatic tissue (Fig 273) The

severance of the prostate is then completed the scalpel cutting directly on to the spatula which thus protects the rectum This preservation of a distal button of prostatic tissue is desirable as it is in the perineal counterpart operation rendering subsequent reparative suturing easier and minimising the likelihood of subsequent post-operative stricture and incontinence

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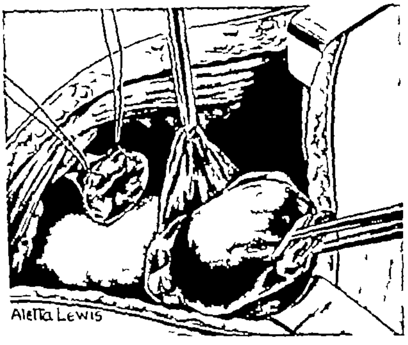

Fig 273 Exposure of the seminal vesicles after sectioning of fascia of Denonvillier (held in Allis forceps). The prostate has been freed from the ectum. The two antero-lateral stay sutures placed in distal prostatic button are shown.

When this mobilisation has been effected, it but remains to sever the gland from the bladder neck The spatula is placed beneath the vesical outlet and the prostate allowed to drop back into its normal position The vesical outlet is then severed as shown in Fig 274, and the prostate with or without attached vesicles removed The bladder neck is now elevated with Allis forceps, and bleeding points are picked up and coagulated Careful digital palpation of the vesical outlet is now made and if there is evidence of sclerosis a wedge is cut, subepithelially from the posterior lip, carefully a oiding the ureteric orifices which can be clearly seen

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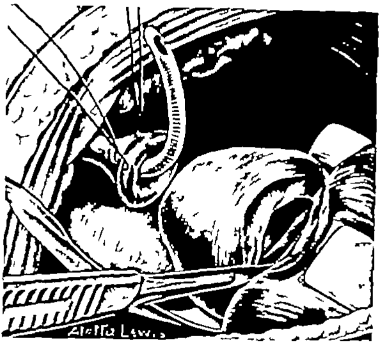

Fig. 274. Division of bladder neck. (Note rectum protected by spatula.)

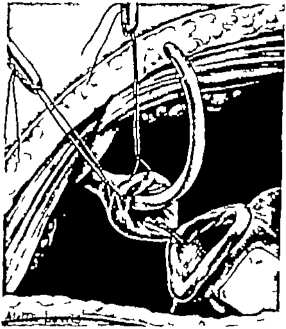

Fig. 275. Apex of trigone approximated to prostatic urethra distally

boomerang needle the apex of the trigone is drawn down to the distal prostatic urethra using plain No. O catgut. (It is simpler to place this suture so that the knot lies within the canal and we have seen no disadvantage from this beyond the occa-

sional subsequent passage of the knot per vias naturales Two postero-lateral sutures are next inserted again utilising the boomerang needle the knots being placed externally The tip of the catheter is now insinuated into the bladder and antero-

Fig 276 Method of approximating vesical outlet to the prostatic urethra distally

lateral approximation effected by utilising the stay sutures placed earlier in the operation through the distal portion of the prostate Figure 276 illustrates the method of suturing and Fig 277 the final approximation.

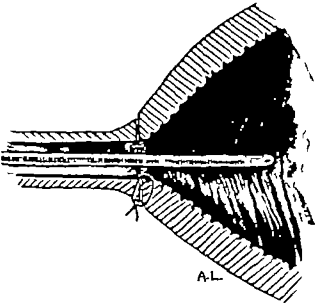

Fig 277 Side view of vesico-urethral reconstruction.

The field is now carefully inspected to verify that all bleeding has ceased If bleeding points are noted they are dealt with by coagulation or alternatively by oxidised celloidin or alginate A corrugated rubber drain is introduced through a separate stab incision in the lower skin flap The aponeurosis is approximated with

a few wire or catgut sutures and the skin closed. The catheter is gently irrigated to ensure that free drainage exists The drain is removed after three or four days but the catheter is maintained for ten days We have not seen stricture or persistent incontinence after this procedure

In this subtotal procedure all the infected prostatic tissue is removed, the urine rapidly clears and the functional results transcend those we have obtained by other techniques when dealing with the calculous gland

RADICAL PROSTATO-VESICULECTOMY

This is the procedure which we adopt when dealing with prostatic carcinoma which appears amenable to surgical extirpation The exposure and initial freeing of the prostate are carried out exactly as already outlined under the heading 'Subtotal

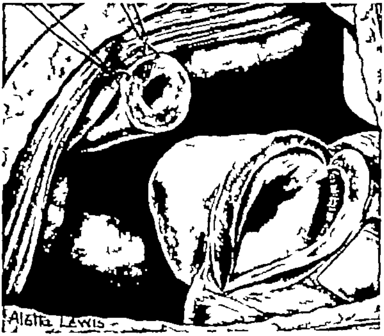

Fig 178 Exposure of trigone and line of section of bladder base

Prostatectomy sa e that where the malignant process appears to invade the gland in its apical portion the distal sectioning must be made through the mobilised membranous urethra If such is necessary there is real risk of subsequent urinary incontinence but the risk must be taken if hopes are entertained of eradicating completely the malignant process In our opinion it is quite unjustifiable to retain a portion of prostatic tissue which may be harbouring malignant cells, in order to maintain urinary continence when one is embarking on radical surgery in the hope of eradicating all the malignancy and so obtaining a permanent cure It is note worthy that se eral advocates of the radical perineal operation ha e stressed the desirability of preserving the prostatic apex

After the membranous urethra or prostatic apex has been sectioned as appears indicated the prostate is freed from below upwards off the fascia of Denon illier

until the attachment of the latter to the posterior aspect of the gland is encountered This attachment is distal to the point of approximation of the vesicles Drawing the prostate in an upward direction puts this fascia on the stretch and it may be safely

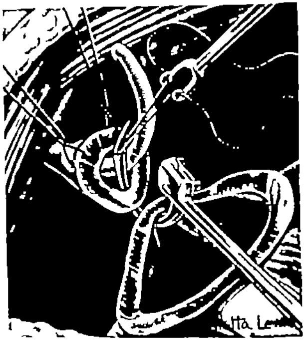

Fig 279 Introduction of posterior suture approximating bladder to distal prostatic urethra.

incised with the scalpel This manoeuvre promptly exposes the vesicles (Fig 273) each of which is freed in turn and the dissection proceeded with in an upward direction until the bladder base has been mobilised

Fig 28 Vesico-urethral anastomosis effected closure of calcal defect.

The copper spatula is now insinuated deep to the bladder neck and the prostate allowed to fall back into its original position The bladder neck is identified anteriorly by palpation and the anterior wall of the bladder incised transversely imme

diately above this level With a stay suture placed in the midpoint of the upper lip of this incision it is drawn upon thus opening up the interior of the viscus and exposing the trigone (Fig 278) This structure is inspected and palpated to ascertain how much must be sacrificed With the diathermy needle the proposed line of section is mapped out and the incision is deepened through the bladder wall until it has been severed The bloc of tissue consisting of the whole (or greater part) of the prostate the vesicles and at least half of the bladder base is now free and is removed

A No 20 Ch Harris type of catheter is now passed along the urethra and the anastomosis effected as depicted in Figs 279 and 280 In our earlier cases we employed suprapubic drainage by means of a small de Pezzer tube through the summit of the bladder to supplement the urethral catheter but latterly have been omitting this and relying solely on the urethral catheter for ten to twelve days

Where we have been able legitimately to preserve a small button of prostatic tissue we have not failed to secure continence but in those cases in which we have felt it essential to make the distal section through the membranous urethra, we have met with a fairly high incidence of stricture and lack of complete control It would appear to be the price the patient has to pay for a complete operation for malignancy

It is as yet, too early to speak of cures as our earliest case scarcely exceeds three years, but we have been on the whole gratified at the apparently high cure rate accomplished to date always remembering the very few cases we have subjected to the radical procedure Recently we have been administering oestrogens for one to two months then reviewing the case and, in a number of cases formerly deemed inoperable we have carried out the radical extirpation.

RADICAL PROSTATO-VESICULECTOMY FOR INFLAMMATORY LESIONS

No satisfactory suprapubic operation exists for the complete eradication of these inflammatory prostates and vesicles and only a few perineal exponents such as Crabtree and Lowsley have advocated surgery for intractable cases We have employed the retropubic technique in a few cases and have been gratified at the minimal post-operative disturbance and ultimate good result evidenced by clearing of rheumatic toxic phenomena and the like In all cases control has been perfect. The technique is a combination of the two radical procedures already described, in that the greater part of the prostate and the whole of the seminal vesicles are removed but the trigone is left intact.

Our experience to date would appear to justify the radical retropubic operations for the types of prostatic disease we have considered

CHAPTER 24

Stress Incontinence of Urine in the Female

CHARLES D READ

In recent years it has become apparent that gynaecologists and urologists everywhere ha e been dissatisfied with the results of the usual operative procedures for the cure of this distressing condition Within the last fifteen years much work on the subject has been published in the French American British and Scandina ian literature All publications show that at the time of operati e repair of uterine and vaginal prolapse sufficient attention is seldom directed towards the cure of the symptom of orthostatic incontinence which frequently accompanies the vaginal descent The result too often is a cure of the prolapse with persistence of the incontinence

Furthermore time has shown that the usual methods of urethroplasty performed by the Marion Kelly or Bonney techniques—buttressing operations—are by no means always successful Various observers ha e assessed the cure rates following these operations at between 70 and 90 per cent On occasions plastic vaginal repair with cure of a prolapse has resulted in the onset of stress incontinence which did not previously exist. Too much attention has been directed towards the urethra itself and too little to the bladder neck Any operation which attempts to cure the condition by producing a urethral stricture is doomed to failure and for this reason Gersuny s urethral rotation is of no a ail

In the ast majority of cases it would appear that the nervous sphincter mechanism of the bladder neck is unimpaired though it seems that in some cases of stress incontinence in nulliparae an inherent nervous weakness is coexistent with the presence of spina bifida occulta Stress incontinence must never be confused with urge incontinence A careful history will distinguish between the two and it must ever be remembered that the surgical procedures outlined here have no place whatever in the treatment of urge incontinence Such surgical procedures will almost in ariably make the symptoms of urgency more marked

MECHANISM OF STRESS INCONTINENCE

Various attempts have been made to ascertain the exact mechanism which allows of the escape of urine when the intra-abdominal or intravesical tension is raised. Many estimations of intravesical pressure have been recorded and in different women the pressures necessary to produce urinary leakage vary enormously—according to the efficiency or otherwise of the bladder neck sphincteric mechanism. W T Kennedy of the Women s Hospital New York, and Dr Joshua Davies of the same hospital have each contributed much to our knowledge of the subject. Kennedy has shown by detailed dissection by urethrograms and by a beautiful series of large micro-sections that in most cases there is fascial damage with the subsequent development of lateral urethral and bladder neck adhesions The result of these adhesions is that instead of the lumen of the upper urethra and bladder neck being circular it becomes transversely elliptical due to the lateral traction Joshua Davies finds that in many cases there is rupture of the urethral and bladder fascia up to a level often as high as that of the entrance of the ureters into the bladder and he describes damage to the plain muscle around the bladder neck and the urethra Einar Thomsen writing independently in Scandinavia concludes that the angulation of the female urethra is an important factor in urinary control but this apparent angulation may well be the result of the anatomical position of the bladder neck, and may not constitute the essential factor in urinary control

Further work by Virgil Counsellor of the Mayo Clinic has confirmed the conclusion of Kennedy and Counsellor has also shown that the results of the usual vaginal procedures for cure from below show a relati ely high proportion of failures He estimates that an early apparent cure rate of 90 per cent falls to a 70 per cent rate in the course of time, and this is the experience of the author

TECHNIQUE OF CYSTOGRAPHY IN STRESS INCONTINENCE

The use of the cystoscope has added little to our knowledge of the condition, but Terence Millin of London conceived the idea of a cystographic study of the bladder and bladder neck under normal resting conditions and under conditions of stress

The following description of the technique is taken from a publication by Millin and the author (1948)

A No 10 F Malecot catheter is passed on a stilette into the bladder The bladder is emptied and by means of a syringe 6 to 10 ounces of a 12 5 per cent solution of sodium iodide is introduced, and the catheter is spigotted. The patient then stands against a vertical x ray screen, with the tube centred on the upper border of the symphysis pubis. She is requested to take a short breath and to remain immobile while the first exposure is made The patient, still in the identical position is then requested to strain down as in the act of defaecation and a second exposure is made on the same film, *i e a double exposure* The second exposure records the bladder neck in its position when intra-abdominal pressure is raised, i e as in coughing, sneezing, or straining As an alternati e method two separate films may be used—one exposure being made in the relaxed upright position and the other while straining *The films are superimposed for reading purposes* (See Figs 281 and 282)

A study of many series of these skiagrams reveals, as anticipated from clinical

studies, that in the normal woman not exhibiting stress incontinence there is no demonstrable descent of the bladder base but in those suffering from such a urinary loss there is very appreciable lowering of the vesical outlet and in advanced cases there is a funnelling of the exitus Moreover from a study of the extent of this descent one can usually estimate the severity of the condition In short it is possible to assess the degree of the incontinence from a perusal of the skiagrams

It can be appreciated that the presence of a cystocele without stress incontinence may give the radiographic appearance of apparent lowering of the bladder neck in

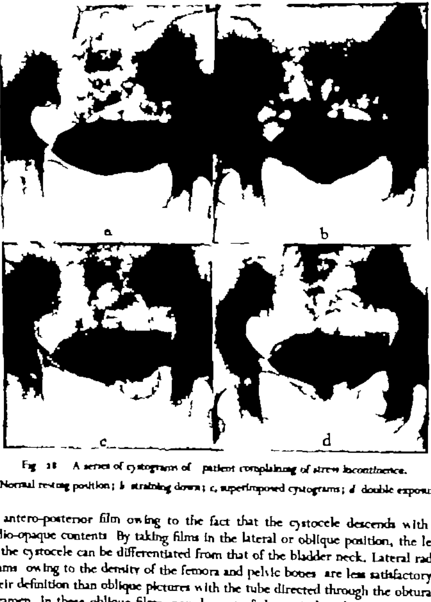

Fig 28 A series of cystograms of patient complaining of stress incontinence. Normal resting position; *b* straining down; *c*, superimposed cystograms; *d* double exposure.

an antero-posterior film owing to the fact that the cystocele descends with its radio-opaque contents By taking films in the lateral or oblique position, the level of the cystocele can be differentiated from that of the bladder neck. Lateral radiograms owing to the density of the femora and pelvic bones are less satisfactory in their definition than oblique pictures with the tube directed through the obturator foramen. In these oblique films non-descent of the vesical outlet can be demonstrated where stress incontinence is absent (Figs. 283 and 284)

CONCLUSIONS TO BE DRAWN FROM RESEARCH AND CYSTOGRAPHIC FINDINGS

From the foregoing researches of Kennedy Davies, and Counsellor and the relatively constant cystographic findings it would appear that in most cases exhibiting stress incontinence there is a descent of the bladder neck on straining due to *faulty musculo-fascial support* *This* descent would appear to be associated with lateral traction due to the existing lateral adhesions and the effect of this descent

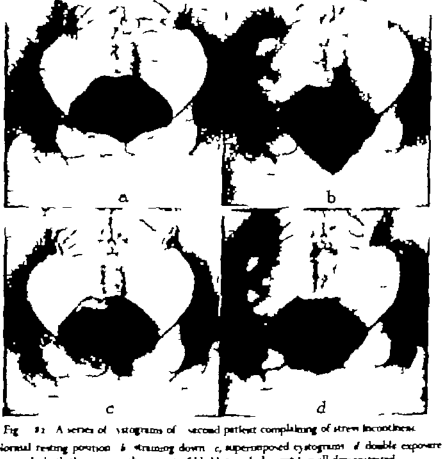

Fig 82 A series of cystograms of second patient complaining of stress incontinence Normal resting position *b* straining down *c*, superimposed cystograms *d* double exposure *In both these series the extent of bladder neck descent is well demonstrated.*

is to open the bladder neck and allow of the escape of urine In the present state of *our knowledge this appears to offer the most likely* explanation of the mechanism of urinary leakage under conditions of increased intra-abdominal and intravesical tension. In other words a normal sphincteric mechanism appears to be unable to function effectively under the abnormal conditions of descent and lateral traction

If this be the mechanism it would appear obvious that the cure of the condition should be dependent on an operative procedure which will elevate the bladder

neck and maintain this elevation under all conditions In addition if the lateral adhesions be freed at the same time the operative procedure should be doubly effective It should thus be the aim in every vaginal surgical approach for the cure

Fig 183 Oblique cystograms in case of marked stress incontinence (two unsuccessful surgical interventions) Note movement of bladder neck downwards and backwards (3 cm on skiagram) on straining (*b*).

of stress incontinence to elevate the bladder neck permanently after having freed the urethra and bladder neck extensively A few patients exhibiting urinary leakage under stress will show little or no bladder neck descent under cystographic examination The condition is neurogenic in origin and usually affects nulliparae who have

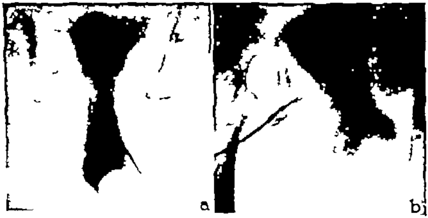

Fig 184.

A-P shift cystogram in case of marked procidentia without incontinence (Foley catheter used here bag being partially distended with neo-hydrol.) Note no downward movement of bladder neck.

b Oblique view of same case showing no movement either downwards or backwards on straining (Cf Fig 183)

suffered from the condition since puberty and a proportion of these will show marked evidence of spina bifida occulta Any operation in such a case is unlikely to effect a cure In order to exclude these it is considered advisable for every patient to have a cystographic examination performed before any operation is undertaken

CHOICE OF OPERATION

The multiplicity of operative procedures advocated for the cure of stress incontinence indicates that in the past the results have been somewhat unsatisfactory Broadly speaking, three methods of approach are available—vaginal combined abdomino-vaginal and abdominal and it cannot be too strongly emphasised that the initial vaginal approach must aim not only at the cure of the prolapse but, in addition, the cure of the incontinence For this reason the first vaginal attempt must involve a radical dissection of the urethra bladder neck and bladder base, with free mobilisation of each and permanent elevation of the bladder neck and bladder base Failure of the first vaginal attempt may result in subsequent multiple operations of increasing severity Again it must be stressed that the performance of a sling type of operation is never justifiable except in those cases in which failure of cure has been experienced following one or more adequate vaginal attempts

Clinically the conditions under review can be grouped into four categories

I Uterine and vaginal prolapse associated with stress incontinence
II Stress incontinence without uterine or vaginal descent or incontinence following an otherwise successful vaginal repair
III Recurrent prolapse with persistence of the incontinence following operative repair
IV Stress incontinence persisting after one or more adequate vaginal repairs in which the special steps taken to overcome the incontinence have failed.

I UTERINE AND VAGINAL PROLAPSE ASSOCIATED WITH STRESS INCONTINENCE

Whether the treatment of the associated prolapse be by simple colporrhaphy for vaginal descent alone or by the Manchester operation, or vaginal hysterectomy and repair for utero-vaginal descent it is imperative in curing the incontinence to take adequate steps to elevate and fix in the elevated position the bladder neck and bladder base This may be accomplished by an approximation of the medial borders of the pubo-coccygeus muscles after upward displacement of the bladder Additional support may be obtained by a careful fascial repair or by the operation of Wilfred Shaw in which the post urethral ligament is sutured to the supravaginal cervix This latter has however the theoretical disadvantage of shortening the anterior vaginal wall and of approximating the cervix towards the pubis The once popular inter position operation accomplished elevation of the bladder and effected a cure but its many disadvantages have led to the operation falling into disrepute Following vaginal hysterectomy by the Mayo technique bladder elevation may be permanently attained by approximation of the medial borders of the broad ligaments with approximation of the upper border of the broad ligaments towards the pubic bone. This forms a shelf on which the bladder rests This shelf is further reinforced by a careful pubo-cervical musculo-fascial repair

TECHNIQUE OF VAGINAL APPROACH FOR THE CURE OF STRESS INCONTINENCE

The operation favoured by the author is a combination of the Kennedy and Davies operations with the addition of a careful pubo-coccygeus muscular repair as described by Treahy and Pacey (1948) of New Zealand (Fig 285)

Stage 1 Access to the subvesical area is obtained by a midline split from cervix to external urinary meatus in cases without uterine descent or by the usual triangular flap dissection in patients in whom there is uterine descent and in whom a Manchester type of operation is contemplated The vaginal and pubo-cervical flaps are well reflected laterally

Stage 2 The bladder and urethra are freely mobilised The utero-vesical space is freely separated but the peritoneal pouch is left intact The urethra is liberally freed especially laterally The base of the bladder is advanced on the supravaginal cervix and a bladder and urethral fascial repair is made by a continuous No O chromic catgut suture extending from high up on the bladder base down to the external urinary meatus

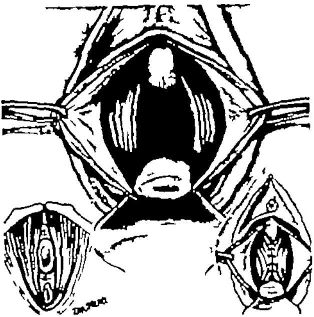

Fig 285 Trealn Pacey operation (diagrammatic) Lower left show anatomy of levator ani muscles in relation t urethra and vagina Centre show pubo-coccygeus muscles well exposed with vaginal fascia retracted laterally with vaginal walls. Lower right show approximation of pubo-coccygeus muscles forming shelf above which rests bladder and bladder neck.

Stage 3 After further lateral dissection of the vaginal flaps and retraction of the bladder neck and urethra to the opposite sides the medial aspects of both pubo-coccygeus muscles are grasped with tissue forceps They are usually easily identified by their pearly white fascial covered edges These two edges are approximated by interrupted No 1 chromic catgut sutures from just behind the level of the external urinary meatus to as far back as the cervix If vaginal hysterectomy has been per formed they can be approximated still further posteriorly

Stage 4 The pubo-cervical fascia is then approximated by a continuous No O or 1 catgut suture and after excision of the redundant vaginal flaps the vaginal edges are approximated

A self retaining catheter is left in situ for seven days and the patient is allowed up on the fourteenth day The patient is kept on a sulphonamide preparation while

the catheter is in situ It will be appreciated that this operation involves an extensive dissection and at times venous oozing from the para-urethral area is considerable The use of a fine diathermy point has been found very helpful in controlling this bleeding

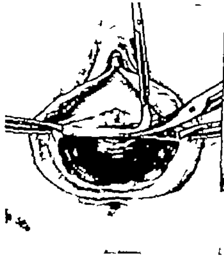

Fig 286

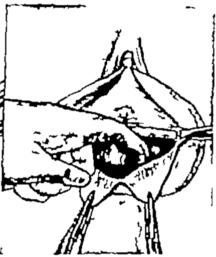

Fig 287

Fig 286 Excision of transverse strip of mucosa.
Fig 287 Retrograde dissection of anterior vaginal wall.

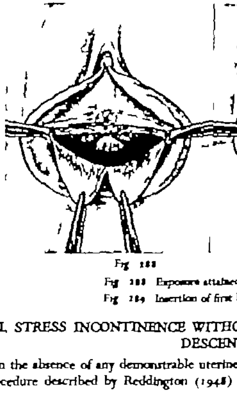

Fig 288

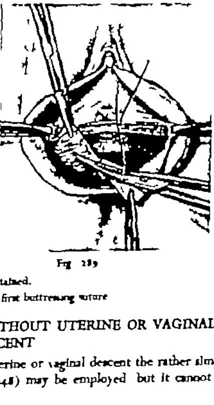

Fig 289

Fig 288 Exposure attained.
Fig 289 Insertion of first buttressing suture

II. STRESS INCONTINENCE WITHOUT UTERINE OR VAGINAL DESCENT

In the absence of any demonstrable uterine or vaginal descent the rather simple procedure described by Reddington (1948) may be employed but it cannot be

overstressed that success in the case of stress incontinence is attained only by a carefully performed repair with liberal freeing of the urethra and bladder

REDDINGTON'S OPERATION

The Reddington technique illustrated here (Figs 286 to 291) consists of excising a transverse ridge of tissue raised by the lateral traction of Allis forceps placed on

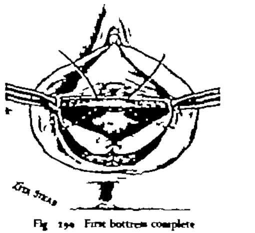

Fig 290 First buttress complete

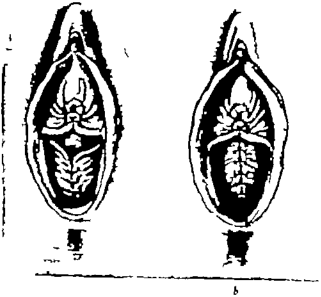

Fig 291 Buttresses tied. *b* Vaginal repair completed

either labium minor at the level of the floor of the urethral meatus A retrograde dissection of the anterior vaginal wall from the urethra and bladder base is performed and the bladder base and urethra are fully mobilised as far as the cervix and especially

laterally For adequate access the vaginal wall is split in the midline A stout needle carrying No 3 chromic catgut is made to enter the mucosa just lateral to the urethral meatus and then made to curve upwards and laterally grazing the periosteum of the ischio-pubic ramus and then turned medially and brought out just lateral to the urethra deep to the mucosal level The needle point then enters the right para-urethral tissue and passes upwards and outwards grazing the ischio-pubic ramus on the opposite side and is brought out just to the right of the urethral meatus By this means a large mass of tissue on either side above and lateral to the urethra is approximated on tying the suture and this has the effect of elevating the urethra upwards and backwards and fixing it Two sutures inserted successively posterior to the first still further elevate the urethra and bladder neck and fix these structures at a higher level A small self retaining catheter is inserted for seven days after the vaginal edges have been trimmed and approximated

Reddington claims 100 per cent success with this procedure in over 100 cases The procedure can of course be incorporated into any operation for the concomitant cure of uterine and vaginal prolapse

III. EXTREME DEGREES OF STRESS INCONTINENCE WITH ASSOCIATED RECURRENT CYSTOCELE

In such patients the choice of operative treatment lies between a repeat repair of the cystocele with special steps to attain elevation and fixation of the bladder neck on the one hand and the combined abdomino-vaginal operation of Aldridge or Studdiford on the other These latter operations enable an adequate vaginal repair to be performed in association with a sling type of operation The results are excellent both in respect to cure of the prolapse and of the incontinence The essential steps of the operations which have been fully described consist of

1 Anterior vaginal incision with separation of fascia, urethra and bladder base
2 The elevation of two strips of external oblique aponeurosis pedicled above the symphysis on either side (Aldridge) Larger single strip (Studdiford)
3 The passage of the fascial strips from above retropubically to surround the proximal urethra and bladder neck and then their suturing together from the vaginal aspect with such tension as to elevate and fix these structures at a higher level (Aldridge)
4 Vaginal fascial repair and suture of vaginal flaps

At present the author reserves this type of operation for those patients in whom stress incontinence is a severe disability and in whom there is evidence in addition of recurrent vaginal descent in spite of previous attempts at repair

IV PERSISTENT STRESS INCONTINENCE

In Spite of One or More Adequately Performed Vaginal Repairs Without Recurrence of Vaginal or Uterine Descent

Patients in this category constitute the 10 to 25 per cent whose vaginal repair operations for the cure of urinary leakage during stress result in failures Most patients in this group have experienced more than one attempt at cure and they may be regarded as the really intractable group It is submitted that for these

unfortunate people the best means of cure is by means of the Millin retropubic sling operation devised by Terence Millin and published in detail by Millin and the author (1948) With very slight modifications the author submits the details of the operation as published It is a purely abdominal operation and effects the suspension of the bladder neck and upper urethra by means of an aponeurotic sling or hammock which has the particular merit of being elastic having a muscular pedicle at each extremity Moreover by virtue of its disposition the sling actually tightens when the intra-abdominal pressure rises and bulges out the lower abdominal wall so elevating the vesical neck under those very conditions which pre-operatively caused the descent of this structure and so allowed urinary leakage

Recently McIntosh Marshall of Liverpool working independently (1948) has come to the same conclusion namely that adequate support of the bladder neck is the all-important factor in urinary control in the female He employs a somewhat similar sling type of operation but his sling is sometimes formed of a free aponeurotic strap of fascia lata In a personal communication he endorses the claims made for such a procedure as the sling operation herewith described

MILLIN'S SLING OPERATION

Preparation of Patient

After a full vulval shave the abdomen is prepared as for any routine abdominal operation After anaesthetisation with full aseptic precautions on the operating table a No 20 Ch. Malecot or Foley catheter is passed into the bladder on a stilette The bladder is allowed to empty and the catheter then gently withdrawn until the expanded head of the Malecot, or the distended 5 c c balloon of the Foley catheter is felt to impinge on the vesical neck. If desired, a light pack may be placed in the vagina The patient is then placed in the full Trendelenburg position and suitably draped

Technique

A generous transverse incision is made at the level of the anterior superior iliac spines slightly convex downwards in the line of the skin creases The incision is carefully deepened throughout its length to expose the aponeurosis of the anterior abdominal wall The flaps are undermined upwards downwards and laterally and accurate haemostasis effected by ligature or diathermic coagulation The anterior sheath of each rectus muscle is now incised in the line of the skin cut and, by passing the closed blades of a pair of long-angled scissors laterally through this incision and then gently opening them, the aponeuroses of the two oblique muscles are freed from the underlying transversalis on each side

The incision previously made in the anterior rectus sheath is now continued laterally through the two oblique aponeuroses to within 2 cm. of the anterior superior spine on each side Both aponeurotic flaps are then freely undermined and from the inferior one a full length strap 1 cm. wide, is cut, pedicled on the right (Fig 292) A second similar strap is next cut pedicled on the left (Fig 293) If the straps have been correctly fashioned it will be noted that about 3 cm of the base of each is muscular and so they will have an elasticity not otherwise obtainable Each strap 15 to 18 cm In length is now wrapped in a warm saline swab The

recti muscles are then separated in the midline care being taken to avoid opening the peritoneum and the retropubic space gently opened up by drawing the pre peritoneal fat upwards After passing a pair of curved Kocher s forceps from within

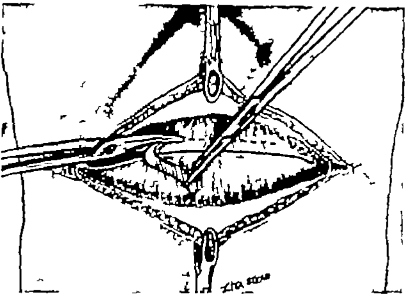

Fig 292 Cutting first aponeurotic strip.

outwards through the middle of each rectus the end of the corresponding strap is seized and drawn through (Fig 294) and again wrapped in a warm saline swab

A suitable self-retaining retractor (Millin or Gosset type) is now inserted into the wound, and the recti spread The retropubic space is thus visualized The

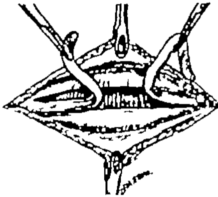

Fig 293

Fig 294

Fig 293 Both aponeurotic straps fashioned

Fig 294. Straps passed through both recti muscles

bladder neck and upper urethra are gently pushed away from the posterior aspect of the pubis the attachments being loose and avascular The expanded end of the catheter will usually be seen and always felt so identifying the level of the bladder

neck. With finger and thumb the urethra with its contained catheter is traced downwards and gently freed from the underlying vagina on each side (Fig. 295). No attempt should be made to isolate the urethra in its entire circumference or it

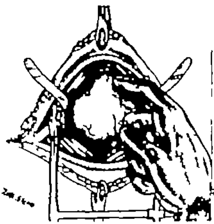

Fig. 295

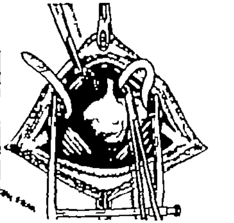

Fig. 296

Fig. 295. Separation of bladder neck and upper urethra from underlying vagina.

Fig. 296. Suburethral tunnel established by passing Millin-Read forceps with right strap grasped in forceps. (Alternative method.)

will probably be torn. Dense adhesions are usually present in the midline on its under-surface especially after previous vaginal operations.

After elevation of the proximal urethra with the thumb and forefinger of the left hand the specially-devised curved forceps are forced through the tough urethro-

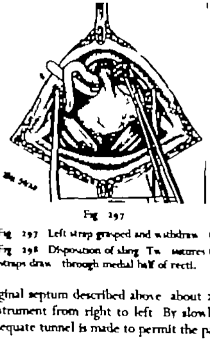

Fig. 297

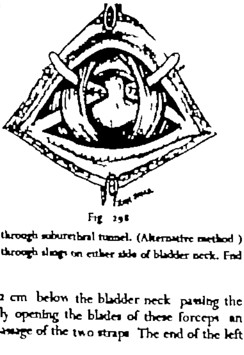

Fig. 298

Fig. 297. Left strap grasped and withdrawn through suburethral tunnel. (Alternative method.)

Fig. 298. Disposition of sling. Two sutures through slings on either side of bladder neck. End of straps drawn through medial half of recti.

vaginal septum described above about 2 cm. below the bladder neck, passing the instrument from right to left. By slowly opening the blades of these forceps an adequate tunnel is made to permit the passage of the two straps. The end of the left

strap is guided down to the opened jaws of the forceps (Fig 296) seized, and drawn through The end of the strap is held with Kocher s forceps and elevated This manoeuvre delineates the suburethral tunnel By passing the forceps through the tunnel from right to left the end of the opposite strap is seized with the forceps and withdrawn (Fig 297) Fine nylon sutures are inserted through the crossed straps on either side of the bladder neck (Fig 298)

A pair of Kocher s forceps is now passed through the junction of the middle and medial thirds of the rectus on each side and the end of the corresponding strap drawn through The ends of the straps are then sutured to each other with 5 N nylon care being taken that the bladder neck is not unduly elevated, so angulating the urethra Two nylon sutures are used for security (Fig 299) This manoeuvre approximates the recti and minimises the risk of divarication The sling has now moreover two points of muscular suspension in the midline in addition to its lateral muscular pedicle

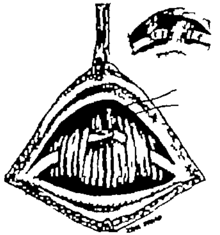

Fig 299 Final suturing of strap ends with nylon. *Inset* Single sling or hammock.

It is thus seen that by this procedure a double sling is produced The operation may be modified by the formation of a single sling or hammock simply by relying on the first series of nylon approximations lateral to the bladder neck (Fig 299 Inset) This is employed if the fascial strips be short, and experience shows that the results of this simple sling are excellent

Occasionally venous haemorrhage of a moderate degree of severity is encountered whilst dissecting the peri urethral area close to the bladder neck. This is due to damage to the friable deep vein of the clitoris or its tributaries entering the neighbouring plexus and will usually cease with gauze pressure Occasionally ligature or *preferably diathermic coagulation, will be necessary*

After the straps have been suitably placed and sutured in position the retropubic space is swabbed free of clots and dusted with sulphanilamide powder A small stab wound is made in the inferior flap and a corrugated drain placed down to the retropubic space *If the second technique has been employed it will be desirable to* approximate the bellies of the recti with a few interrupted catgut sutures loosely tied. (In the first technique the sutured straps approximate the recti sufficiently)

The upper and lower aponeurotic leaves are now united with interrupted sutures of No 2 chromicised catgut In some cases the leaves come together in the midline only under tension and it is desirable to straighten out the table and flex the thighs to reduce the tension The skin and subcutaneous tissues are approximated with silkworm gut and Michel clips It is a good plan also to insert a small rubber drain at each extremity of the wound into the subcutaneous tissues to prevent the formation of a haematoma A pressure dressing is applied The cathether is irrigated gently to ensure that the bladder drainage is free and may require an advancement of 2 to 3 cm into the bladder

Post-operative Care

The patient is nursed sitting up in bed; early movements are enjoined The catheter is connected by sterile tubing to a bedside Winchester Irrigations are employed only if the drainage should be faulty A prophylactic course of sulphadiazine 0 5 to 1 gm every six hours is given, and a copious fluid intake insisted

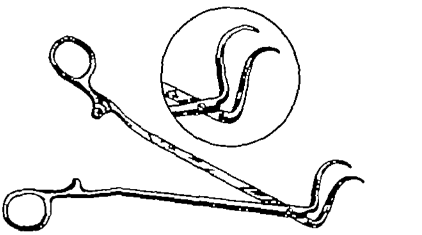

Fig. 300 Millin-Read forceps. (Hawkins, New Cavendish Street London.)

upon A variable amount of sanguineous discharge will escape through the stab wound during the first twenty-four to forty-eight hours necessitating a change of dressings The small subcutaneous drains are removed at the end of twenty-four hours The catheter is usually removed on the seventh post-operative day but if there is suspicion of injury to bladder neck or urethra it may be advantageously left in for ten days The retropubic drain is removed on the third or fourth day and the patient allowed out of bed on the seventh day She is usually ready to go home on the fourteenth or sixteenth day

In a small proportion of cases a post-operative suprapubic urinary leak will occur when the catheter is removed This will necessitate the reinsertion of the catheter for a further few days With increasing experience we seldom see this complication. It is of little moment but will prolong the hospital stay Not infrequently on removing the catheter some vesical irritability is noted but this usually soon passes off Only rarely is any difficulty of micturition noted after withdrawing the catheter but we make it a rule that if urine has not been voided four hours later the catheter is reinserted. In one early case where this rule was not observed the retention was

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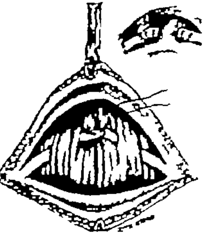

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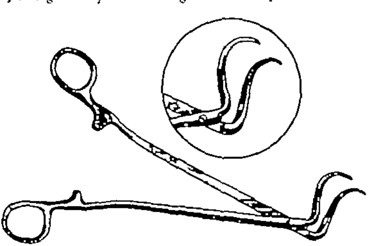

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only discovered many hours later by which time extreme vesical distension had led to marked tautening of the straps Urethral catheterisation proved impossible and suprapubic cystotomy was carried out In such an emergency a suprapubic puncture with a lumbar puncture needle would relieve the tension and a catheter could then be passed The above case proceeded to a complete cure without further trouble

Operative Difficulties

These are seldom of moment

Haemorrhage The tearing of the deep vein of the clitoris or the associated plexus may cause a troublesome venous ooze but this, as *mentioned above will usually* respond quickly to gauze pressure Ligature or coagulation may be required

Previous Abdominal Operations Many of our cases had midline subumbilical scars and apart from the necessity of a careful dissection of the aponeurotic leaves from the scar little difficulty was met In one case where a large ventral hernia existed, especial care was required In five cases a previous suprapubic cystotomy had been made and here dense adhesions between the anterior wall of the bladder and the parietes were encountered They respond to careful sharp dissection and the cavum retzii will be found to open readily

Previous Vaginal Repairs In more than 90 per cent of our cases one or more vaginal repair operations had preceded the sling (in one case there were twelve previous attempts!) The adhesions binding the under-surface of the urethra and bladder neck to the vagina are of necessity denser after vaginal interventions than in those cases in which no such operation has been carried out but they yield readily to puncture with the special forceps designed for the purpose Most operators undertaking the sling procedure for the first time find the chief difficulty in defining the plane between the urethra and vagina and are surprised at the force sometimes necessary to perforate the dense bands connecting these structures especially *where several vaginal operations have previously been carried out*

Operations Combined with the Sling Technique

On five occasions the author has performed a total hysterectomy on four occasions a subtotal hysterectomy and on three occasions a shortening of the round ligaments in association with the sling technique This of course involves a deliberate opening of the peritoneum the performance of the intra-abdominal procedure careful closure of the peritoneum and a subsequent sling operation

Complications

Post-operative Urinary Obstruction In our early cases a desire to make certain of a cure of this distressing complaint tended to encourage overcorrection of the bladder descent, and an unduly tight sling resulted. Following this error in technique a few patients complained of difficulty of micturition, usually shortly after leaving hospital On endoscopic examination they were found to have as expected a transverse ridge at the bladder neck analogous to the median bar obstruction found in the male In the lesser degrees this will respond to dilatation with a Kollmann s instrument or backward traction to stretch the straps, using a sound in situ In more severe cases (three in our series) a per-urethral resection of the bar was carried out with

complete relief of symptoms Obviously care must be taken in carrying out this resection to avoid complete severance of the straps especially in early post-operative days (at a later date the bladder neck has probably become fixed in it high position by adhesions) and of course to avoid perforation of the vagina and so cause a vesico- or urethro-vaginal fistula.

Early post-operative difficulty *of urination on removal* of the catheter has already been mentioned

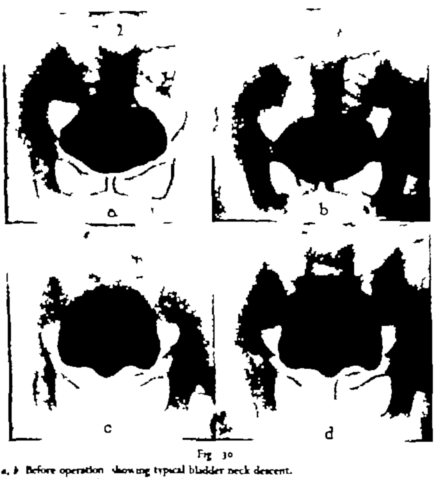

Fig 30

a, b Before operation showing typical bladder neck descent.

d After Millin sling operation and cure of stress incontinence. Neither show appreciable descent and both show elevation of bladder neck The alteration of bladder base contour due to the sling is well shown.

Sepsis This has been encountered in five cases and the result of the operation has been a disappointment in three of these patients Diffuse retropubic sepsis has resulted in shedding of the nylon sutures and on three occasions incision and drainage of a retropubic abscess has been necessary

Post-operative Urinary Leakage This will occur in a small proportion of cases but with decreasing frequency as experience grows Occasionally in removing the catheter on the seventh post-operative day urinary leakage may occur from the stab wound This indicates that the bladder neck or urethra has been damaged and merely

requires reinsertion of the catheter for a further few days In only one case has a fistula persisted for more than twenty days In this case the sling was too tightly applied and the proximal urethra sloughed with resulting fistula Repair was effected by the vaginal route some six months after operation and although the fistula is closed the stress incontinence persists

Post-operative Urgency In some 10 per cent of patients post-operative urgency is experienced to a varying degree This would appear to be due to irritation of the bladder base by the presence of the fascial sling In some cases there is a co-existent urinary infection which may be cleared up quickly on a course of alkalis and sulphonamides Within six to eight weeks this urgency invariably subsides

Results of Millin's Sling Operation

The author has to date personally performed this operation on 126 occasions with a single operative death due to a pulmonary embolus on the tenth post-operative day The youngest patient was 35 years of age and the oldest 65 years

An analysis of the 126 operative results shows that 91 patients describe themselves as completely cured Of the 35 remaining, 21 describe the result a 90 per cent cure *and these are perfectly satisfied with their result and refuse any further attempt at* improvement Of the remaining 14, one is dead and 13 state that there is no improvement One of these was the patient whose urethra was divorced from the bladder neck and subsequently she had her fistula repaired, but she still complains of stress incontinence Three of the 12 developed post-operative retropubic sepsis, which appeared to vitiate the result, and in the remaining 9 it would appear that there was insufficient elevation of the bladder neck at operation—a technical fault.

One of the cured patients had experienced nine previous attempts at cure In another failure must be acknowledged with a sling, after twelve previous unsuccessful attempts by other means

At the time of writing, Wilfred Shaw of London has published his new procedure of placing a free fascia lata sling under the urethra, the sling being suspended above from the pubis This necessitates drilling holes in the pubic bones He claims good results in the small series he has treated by this method The author as yet has had no experience with the operation

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PART IV

Extremities

CHAPTER 25

Arthrodesis of Hip, Knee, and Ankle

O J VAUGHAN JACKSON

An arthrodesis of any joint is essentially in the great majority of cases a procedure in the last resort when all other methods of treatment have failed to preserve the function of the joint In certain instances, as for example, in the tuberculous hip hopes of preservation or restoration of joint function have often to be discarded early and an arthrodesis may be undertaken comparatively early in the course of the disease with the object of securing immobility in the diseased area and of diverting along a safe path those stresses and strains that would normally pass through the joint.

The three great aims of any arthrodesis are then first the relief of pain second, the restoration of stability and third, the arrest of disease Conditions which may produce one or more of these indications are clearly numerous In the three great weight bearing joints hip knee and ankle degenerative arthritis is by far the commonest indication and under this heading are grouped the majority of a diversity of conditions calling for arthrodesis

ARTHRODESIS OF THE HIP

INDICATIONS AND CONTRA INDICATIONS

In the hip joint the degenerative arthritis may be the so-called primary degenerative arthritis of the elderly (*malum coxae senilis*) unexplained except on the wide and comparatively little understood basis of general senescence Secondary degenerative arthritis *may result from any condition which interferes with the normal* structure and function of the hip and a classification of these conditions becomes for all practical purposes a classification of all hip conditions, omitting only malignant disease except in a very occasional and unusual case

While a full classification of these *conditions may not be called for here since it is* the secondary degenerati e arthritis or its unmistakable imminence that constitutes the indication for arthrodesis, it may be well to consider a short list of the

commoner conditions which lead to the ultimate disorganization of the joint. These are

1. Congenital conditions
   Congenital luxation and subluxation of the hip
2. Conditions of the epiphyses in adolescence
   Perthes disease
   Coxa vara
   Slipping of the capital epiphysis
3. Traumatic conditions
   Fractures and dislocations
   Post-traumatic avascular necrosis
4. Inflammatory conditions
   Old tuberculous disease
   Old pyogenic arthritis
   Rheumatoid arthritis (*especially when old and burnt out*)
5. Miscellaneous
   Neuro-arthropathies
   Caisson disease
   Any cause of unfair wear and tear; e.g. loss of, or dysfunction in, the opposite limb. Certain cases of poliomyelitis and other paralyses.

Apart from degenerative arthritis arthrodesis may be called for by simple paralytic instability either flaccid or spastic though this is infinitely less common than in foot ankle or knee Again it may be necessary as already mentioned, for the anatomical and physiological *short-circuiting of active disease. Especially is this so in* the case of tuberculous disease which unlike pyogenic arthritis exhibits no marked tendency to heal by bony ankylosis and which therefore may also call for a late arthrodesis for the relief of pain in an unsound fibrous ankylosis

Contra-indications

Age and General Health of Patient Contra indications to arthrodesis of the hip are fortunately not numerous The patient s age and general health may rule out the procedure which by whatever method, is a fairly formidable business. In this connection it must be stressed that the after treatment, involving two to four months of immobilisation in a plaster spica is for an elderly patient, as formidable an obstacle to be surmounted as the operation itself Efforts have been made to shorten the period of immobilisation with success in certain cases but even then immobilisation has still to be protracted and the tendency in seeking for consistently sound fusions is always towards longer rather than shorter immobilisation A limited operative procedure to which reference will be made later in which reliance is placed on rigid internal fixation may provide a satisfactory answer to this problem, but it is yet to be proved

Fixity of the Opposite Hip Of local conditions the one absolute contra indication to arthrodesis is fixity of the opposite hip unless it is proposed to carry out an arthroplasty on that hip The plight of a patient with two stiff hips is dire indeed. Walking is all but impossible and it requires little imagination to comprehend the aggregate of miseries involved in inability to sit inability to wash adequately and the extreme difficulty of exercising the natural functions (Fig 302)

Impending Fixity of Opposite Hip Together with complete fixity of the opposite hip

obvious impending fixity of this hip as in advanced bilateral degenerative arthritis must constitute an absolute contra indication if for any reason there is no prospect of being abl to restore its mobility Cases with early arthritis of the opposite hip are potentially a harder problem and require some judgment as to whether the hip will last in reasonable comfort for as long as the patient will need it In the hip s favour will be the relief from unfair wear and tear when the fused hip once more does its share and probably more than its share of weight bearing Fortunately most of such hips are susceptible of treatment by cup-arthroplasty

CUP ARTHROPLASTY It may be asked why not treat both hips by cup-arthroplasty? Why not indeed? Clearly a good result of a cup-arthroplasty is far and away the best solution to the probl m of the disorganized hip joint and the eminent originator of this operation now seldom if ever carries out an arthrodesis But it requires very

Fig 3 2 A case suitable for arthrodesis—unilateral degenerativ arthritis. Note the degenerativ cysts in femoral head and acetabular roof; the latter might cause difficulty with internal fixation Not also the overhanging acetabular lip.

considerable skill experience and judgment to say nothing of exactingly meticulous after-care to obtain consistently good results with the cup-arthroplasty And it must be faced that the capacity to withstand wear and tear of those wonderful joints, that reform themselves so miraculously under the moulding of the vitallium cup and to endure for the remainder of the patient s life-time is not even now unavailably established

To obtain consistently good results with arthrodesis of the hip is much easier and no matter how much the technique of cup-arthroplasty is improved, standard ised and brought within the reach of the occasional practitioner it seems clear that arthrodesis of the hip will remain the more certain operation in average hands

A Stiff or Arthritic Knee on the Same Side as the Affected Hip Such a knee is a contra indication though not necessarily an absolute one It is well known that a stiff knee of greater or less degree is the most frequent and consistently troublesome compli

cation of an arthrodesis of the hip but even so if the patient has only the few degrees of flexion that will enable his foot to clear the ground when walking, he will remain, on balance, grateful if he has been relieved of the pain of an arthritic hip Therefore one need not be too chary of an arthrodesis if the knee is already partly disabled.

Lumbar Arthritis Similarly if the hip has a long-standing fixed flexion deformity the lower lumbar spine may be the seat of secondary bony deformities and an associated arthritis It may be very inadvisable to do anything that will tend to force straight the lumbar lordosis in such cases, as the patient may well complain later of his back as much as he did previously of his hip Nevertheless, this does not necessarily rule out an arthrodesis Rather does it indicate an arthrodesis with more flexion at the hip than one might otherwise adopt It must be emphasised that it is lumbar arthritis not mere lordosis, that is the contra-indication A healthy lumbar spine will allow correction of its lordosis without pain

Economic Factors Finally one has to consider economic factors There will be an immediate period of three to four months in hospital This will be followed by many months of rehabilitation and it will not be safe to think in terms of a final result for at least a year from operation though this does not necessarily preclude wage-earning For several months after leaving the hospital the patient will need much help with day to-day problems—dressing, washing and so on Before embarking, therefore on an arthrodesis for an impoverished solitary widow it will be well to go closely into the problem with the almoner

But other things being equal the average patient can look forward to a painless stable hip and the ability to walk and to stand as much as he is likely to want he may well run, if not speedily he will be able to sit albeit slightly askew Paradoxically the absolute but painless fixation of the hip produces, by banishing muscle spasm, a subjective sensation of enhanced movement. On the debit side he will have difficulty in putting on his sock and in lacing his shoe but these are problems that a little ingenuity easily overcomes, particularly if knee movement is free

METHODS OF ARTHRODESIS OF THE HIP

These can be divided into two great groups, intra-articular eminently suitable for a hip the seat of degenerative arthritis and extra-articular more suited to a hip the seat of infection, old or recent since the operation avoids entering the diseased area

Intra-Articular Arthrodesis with the Tri Fin Nail (Watson-Jones)

First Stage SURGICAL EXPOSURE The hip is exposed through a Smith Petersen or modified Smith Petersen incision This incision follows the line of the iliac crest from a point 2 inches from the anterior superior iliac spine to the spine itself and then straight down the front of the thigh for about 5 inches between the sartorius medially and the tensor fasciae femoris laterally It is not necessary to carry the incision as far back along the crest as is usually shown nor to strip more than a small portion of the glutei from the outer face of the ilium

The normal Smith-Petersen approach then lies in the cleft along the medial margin of the rectus femoris having carefully dissected the sartorius from its attachment and stripped with it the anterior portion of the iliacus from the inner face of the ilium The origin of the rectus is then dissected free and turned laterally

It is particularly important to identify the nerve to the rectus entering its medial border towards the lower end of the wound and to protect it from subsequent damage This approach gives a beautiful exposure of the hip which is necessary for the meticulous work of a cup-arthroplasty but for the less refined procedure of arthrodesis it is not strictly necessary and an adequate exposure can in most instances be achieved by lea ing the rectus attachment intact and approaching the hip at the outer border of the medially retracted rectus (Fig 303)

CAPSULECTOMY With either method the next step is to incise the capsule of the hip joint on its anterior aspect and in the line of the long axis of the femoral neck, converting the incision into a T by a cross incision following the margin of the acetabulum This allows two triangular flaps of capsule to be turned back exposing the femoral head The synovial membrane is usually thickened villous and un

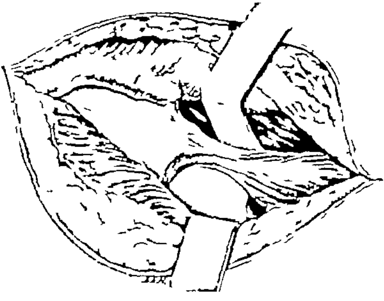

Fig 3 3 Modified Smith-Petersen approach, with subperiosteal stripping of soft tissues from the inner face of the ilium. The glutei can be resutured to the undisturbed attachment of the abdominal musc lature The rectus origin has not been detached

healthy the flaps obscure one s vision and for both reasons they are better removed A more extensive capsulectomy may well prove con enient, and it is a simple matter to find the plane of clea age between the capsule and surrounding muscles and cut the capsule away from the superior and inferior aspects of the femoral neck.

DISLOCATION OF FEMORAL HEAD FROM ACETABULUM The next step is to dislocate the femoral head from the acetabulum by external rotation of the femur but before this can be done it is often necessary to remove with the osteotome the overhanging osteophytic lip from the anterior and superior margin of the acetabulum If this is not done it is quite possible to fracture the femoral neck when trying to dislocate the hip Moreover the dislocation of the joint can produce considerable shock and the more easily and gently the manoeu re can be carried out the less is the shock likely to be

TECHNIQUE OF FIXATION The degenerate articular cartilage and underlying

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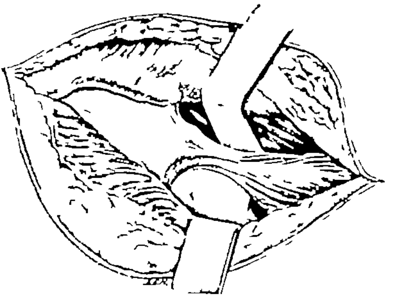

Fig. 303. Modified Smith-Petersen approach, with minimal stripping of soft tissues from the inner face of the ilium. The glutei can be resutured to the undisturbed attachment of the abdominal musculature. The rectus origin has not been detached.

healthy; the flaps obscure one's vision, and for both reasons they are better removed. A more extensive capsulectomy may well prove convenient and it is a simple matter to find the plane of cleavage between the capsule and surrounding muscles and cut the capsule away from the superior and inferior aspects of the femoral neck.

DISLOCATION OF FEMORAL HEAD FROM ACETABULUM. The next step is to dislocate the femoral head from the acetabulum by external rotation of the femur but before this can be done it is often necessary to remove with the osteotome the overhanging osteophytic lip from the anterior and superior margin of the acetabulum. If this is not done it is quite possible to fracture the femoral neck when trying to dislocate the hip. Moreover, the dislocation of the joint can produce considerable shock and the more easily and gently the manoeuvre can be carried out the less is the shock likely to be.

TECHNIQUE OF ERASION. The degenerate articular cartilage and underlying

sclerosed bone are now removed from the femoral head with the osteotome Accurate shaping of the femoral head is not of particular importance the essential being to remove the degenerate surface down to healthy bleeding, cancellous bone

Next the sclerotic bone lining the acetabulum is removed with the gouge It is wise to begin at the lowest or posterior part of the acetabulum otherwise the blood running down from a higher rawed portion may obscure the field and cause difficulty Owing to sclerosis and the thinness of the walls of the acetabulum it may not always be possible to expose bleeding *cancellous* bone in its lower portions but it is essential to success to expose it in the thick overhanging roof of the acetabulum

OBTAINING A SUPPLY OF CANCELLOUS CHIPS A supply of cancellous chips is now necessary There is considerable evidence of their high osteogenic capacity and value in any fusion but whatever one believes in this respect something is needed

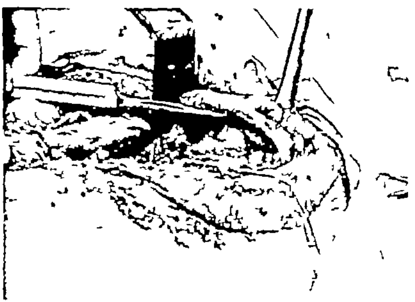

Fig 304 Osteotomy of outer table of ilium preparatory to turning up a "lid" of iliac crest in order to obtain cancellous chips.

as a space filler since one has enlarged the acetabulum and diminished the femoral head and there is no longer anything approaching a congruous fit

The anterior portion of the iliac crest is therefore turned upwards and medially like a lid, by a cut with an osteotome parallel with and just below the iliac crest in the outer table of the bone The lid is levered up and hinges back by a break occurring in the inner table along the line opposite the osteotomy (Fig 304) A sufficient supply of chips can then usually be gouged out from between the two tables of the bone and from the "lid" itself (Fig 305) If more chips are required, some of the outer table can be turned down further back and a further supply obtained. Smith-Petersen advocates the removal of the anterior superior iliac spine itself as he finds it apt to produce a tender prominence under the scar Doubtless this is so when the spine has been completely denuded of soft tissues in the approach to the hip for an arthroplasty But using the modified approach described above the writer

finds that with the abdominal musculature still attached to the iliac crest the glutei can be resutured firmly to the crest holding the lid securely in position and subsequent complaint of a tender prominent spine is unusual

PACKING THE JOINT WITH CANCELLOUS CHIPS The cancellous chips are now transferred to the acetabulum and spread around to line it The femoral head is reduced and the chips packed tight with any suitable rammer or punch. The wound is then closed and a one and a half plaster spica applied (to the toes on the affected side and to above the knee on the opposite side) The position of the hip should normally be one of a few degrees of flexion neutral rotation and neutral abduction-adduction, or at most a few degrees of abduction

This completes the first stage To carry out the introduction of the nail at the same sitting is unnecessary and would make the operation unduly long and risky

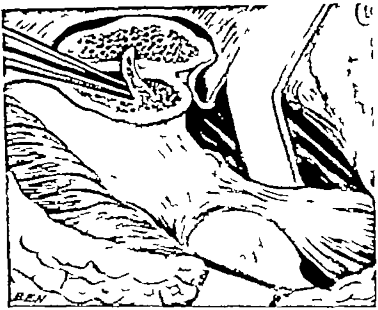

Fig 3 5 Method of gouging out cancellous chips from between the two tables of the ilium in the region of the anterior superior iliac spine

Second St ge ADJUSTMENT OF POSITION OF HIP Three weeks later the hip is in a sticky state which allows any necessary adjustment of position. The patient is placed on an orthopaedic table and the position adjusted In order not to disturb this position, with possibly embarrassing results after the nail is inserted it is necessary to be particularly careful if lateral x rays of the hip are to be taken. The opposite leg may be unwittingly abducted so much to allow the x ray tube to be placed that abduction occurs in the arthrodesed hip resulting in a final fusion in o er-abduction for which one will not be thanked Generally speaking, it is possible to dispense entirely with the lateral view and so avoid this error

FIXATION WITH THE TRI-FIN NAIL. The approach is made as for the nailing of a fractured femoral neck by a vertical incision over the trochanteric region, but the incision must extend several inches further down the thigh, as the long tri-fin nail is not inserted in the axis of the femoral neck but much more vertically in order for it

to obtain a firm grip on the thick portion of the ilium above the acetabulum. An additional advantage of this nearly vertical alignment is that weight-bearing later will result in impaction rather than shearing strains on the nail (Fig 306)

Reference to the antero-posterior view of the hip will allow one to judge accurately with very little experience or trial and error where to gouge the small hole in the cortex of the subtrochanteric region for the entry of the Watson-Jones guide wire This guide is introduced using the chand chuck, for several inches as convenient and an A P view taken to check its alignment The guide is within the femoral neck from which it cannot escape Any malalignment will result in the

Fig 306. A well placed tri-fin nail Note its nearly vertical alignment and firm grip upon the ilium.

point engaging in the cortex which will resist its progress If this occurs the guide is withdrawn and its alignment slightly altered till finally it passes easily and a fresh A P view confirms that it is satisfactorily across the joint and engaged in the ilium. The length of guide left protruding subtracted from its known length gives the length of the nail required The nail is threaded over the guide driven home the guide extracted and a final x ray taken

While driving the nail it is of great importance to measure after every two or three strokes the length of guide protruding These guides are springy and may follow an almost imperceptibly curved course The sharp edge of the cannula at the business end of the rigid nail may engage with and cut into the metal of the

guide carrying the guide forward with it This may result at best in extreme difficulty in removing the guide in breaking of the guide or at worst in a considerable intrapelvic protrusion of the guide point menacing divers viscera and major vessels (Figs 307 and 308)

The plaster spica is now replaced.

After-Treatment After treatment consists in the first place of four months immobilisation in plaster Some few cases will not need as long so it is reasonable to remove the plaster at thirteen weeks for clinical and radiological assessment of the fusion replacing it if necessary In almost every case fusion will be sufficiently firm at eight weeks to allow of bivalving the lower leg portion of the plaster to

b

Fig 307

The guide wire has been severed by the nail

b The reason—the guide wire was bent Note also the prominence of the lesser trochanter indicating that this hip is being fused in too great external rotation.

permit knee flexion exercises It is probably wise to keep the posterior shell and bandage it back between exercises to be sure of controlling rotation movement of the limb within the plaster (Fig 309)

As soon as the fusion is judged firm the patient is taken out of plaster and allowed to move free in bed for a few days before getting up with crutches and beginning to bear gradually increasing weight on the leg Any complaint of real and particularly of persistent pain in the hip will call for an immediate review of the situation Slight muscular aches are of little consequence and are to be expected

Throughout the bed period general physiotherapy and exercises within the limits imposed by the plaster are carried out Static quadriceps contractions are important and it is wise to teach the patient these before the operation

Complications Apart from those already mentioned complications are fortunately not frequent The stiff knee is avoided or treated by early active knee flexion exer

cises Imperfect or too brief immobilisation in plaster may result in loosening of the nail If slight rocking movements are going on within the plaster this may be

Fig 3 8 Marked intrapelvic protrusion of a broken guide wire point. Note also the rarefaction around the nail point and smaller guide wire fragment due to electrolytic action between the two dissimilar metals.

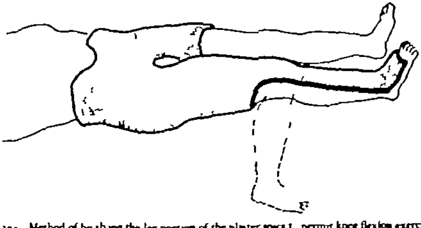

Fig 309 Method of bivalving the leg portion of the plaster spica to permit knee flexion exercises.

spotted in an x ray when the nail will be seen to be outlined by rarefaction, greatest in extent at each end of the nail where the excursion is greatest, least at, roughly

its midlength where the fulcrum lies (Fig 310) Symmetrical and parallel outlining of the nail is of more serious import No rocking is taking place and the rarefaction is probably due to sepsis Occasionally by some ill-understood combination of forces, the nail is slowly extruded (Fig 311) The extruding force is evidently great as it may cause fracture of a retaining Pidcock pin A badly placed nail with a poor grip on femur or ilium may bend or fracture (Figs 312 and 313) Any of these vagaries of the nail may cause an unsound fusion, which if painful may necessitate a revision of the arthrodesis

Though infrequent these complications occur sufficiently often to drive home the lesson that a plaster spica alone provides extremely imperfect immobilisation in

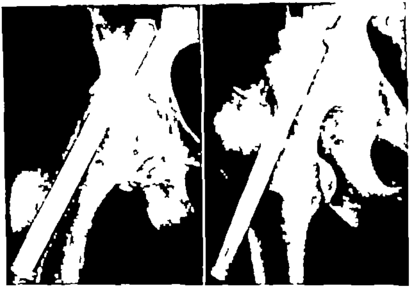

Fig 310 Fig 311

Fig 310 Outlining of nail by rarefaction due to rocking In this case actually no erosion of joint surfaces was carried out and fusion was attempted with the nail alone The x-ray however shows nicely the type of rarefaction rocking will produce

Fig 311 Spontaneous extrusion of tri fin nail

the hip however thin the patient The addition of internal nail fixation to the operation has reduced the incidence of unsound fusions from 60 per cent to 10 per cent or less (approximate figures)

Modified Intra Articular Arthrodesis with Lag Screw Fixation

McKee has recently described a method of arthrodesis which may prove of use in the elderly as both the operation and the after treatment are less exacting Briefly the method is to approach the hip along the upper border of the femoral neck through a lateral incision Without dislocating the hip the upper portion of the femoral head and the weight bearing roof of the acetabulum are gouged out and replaced with cancellous chips A long pin with a lag-screw end is then passed up the femoral neck from the subtrochanteric region till the screw grips the ilium securely A short plate similar to that used in the McKee nail and plate for inter

Fig 312

Fig 313

Fig 312 The nail has poor grip on femur and ilium. It is unsupported at its middle and has bent despite plaster spica, soon after its insertion, as is shown by the slight extent to which fusion has progressed.

Fig 313 The nail is not vertical enough and has been broken by bending and shearing strains at the joint line

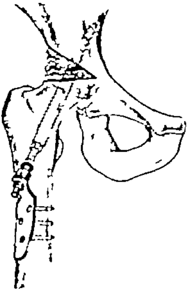

Fig 314 Lag screw fixation in McKee arthrodesis.

trochanteric fractures is placed over the threaded outer end of the pin and screwed to the femoral shaft The apparatus is then hove up taut by tightening the locking nut (Fig 314)

The writer can vouch for the impressively rigid impaction and fixation secured but though McKee has obtained satisfactory fusions relying only on this internal fixation and a period of rest in bed of a few weeks one feels that those formidable forces that can loosen extrude bend or fracture a tri-fin nail will influence him gradually in the direction of longer rest in bed and of supplementary external fixation and probably some modification of the apparatus to counteract rotation strains which it cannot control Nevertheless it is in the frail and elderly that these forces will be least, and the method holds promise of relief for those for whom a full-dress arthrodesis is deemed too formidable and it clearly merits trial and experiment

It is likely also that the method will pro e most successful in hips that are already very stiff as was found by Watson Jones in attempting to achieve fusion using the

Fig 3 5 Illustrating the power of the adductors. Bending within guarding plaster spica, of Küntscher nail used for fracture of the femoral shaft I case of Paget disease

tri fin nail without erasion of the joint surfaces The essential factor in obtaining bony fusion is real immobility and loosening of any internal fixation apparatus is likely in any hip that has an appreciable range of movement before fusion.

Extra-Articular Arthrodesis of the Hip

Methods of extra-articular arthrodesis divide naturally into two groups—those above the hip joint (ilio-femoral) and those below (ischio-femoral) The first group bearing such names as Hibbs and Albee are perhaps a little transatlantic in flavour for a description of techniques in British surgery Nevertheless they are of proved high alue and no slur upon them is intended if they are only mentioned here for some of their disadvantages compared with a more recent British procedure

One of the main difficulties arises through the power of the adductors of the

thigh It is well known that these muscles are powerful enough to fracture grafts and bend steel plates and Kuntschner nails in the fractured femoral shaft even within a guarding plaster spica (Fig 315) A graft between ilium and trochanter is therefore put under tension by these muscles and it is not surprising that it is often difficult to get sound fusion at both ends of the graft One end or other is only too likely to pull out Moreover the graft is a long one and will take a long time to become revascularised and hypertrophied

Another difficulty is encountered owing to the tendency of inflammatory disease of the hip to spread upwards into the ilium and outwards to the trochanter rather

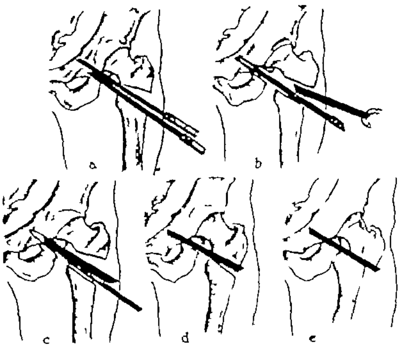

Fig 316 Essential steps in Brittain ischio-femoral arthrodesis.

Cutting ischial socket with chisels passed through the osteotomy
b c d Insertion of the graft and removal of the second chisel.
Final position with lower femoral fragment displaced inwards.

than downwards It may be extremely difficult therefore to keep clear of diseased tissue with an ilio-femoral graft

An ischio-femoral graft on the other hand is under compression from the pull of the adductors, it is shorter and it more easily keeps clear of the diseased area.

Though Calve predicted and Trumble first carried out, the ischio-femoral arthrodesis in this country the name of H A Brittain is the one firmly associated with this operation

Technique of Ischio-Femoral Arthrodesis The operation, fully described in this surgeon's excellent book, consists briefly of a low intertrochanteric osteotomy running inwards and slightly upwards the passage of long graduated chisels inwards and slightly backwards through the osteotomy till the ischium is felt the cutting

with these chisels of a socket in the ischium to receive the end of a stout 5-inch tibial graft, which is slid into place along one chisel the other having been removed the removal of the second chisel and the final firm impaction of the graft and inward displacement of the upper end of the lower femoral fragment until if possible the lesser trochanter impinges on the ischial tuberosity (Fig 316)

The whole new arrangement of structures locks firmly together and indeed to be confident of success one should be able to grip the outer end of the graft with a forceps and literally to shake with it the patient's femur and pelvis as a firm and rigid whole

One or two points about the operation should be stressed If it is being performed upon a tuberculous hip the timing is important Radiological and clinical checks should confirm the quiescence of the disease and the arrest of bone destruction

Fig 317 Case of tuberculosis of the hip joint Brittain ischio-femoral arthrodesis six months after operation. The graft is firmly united and considerable hypertrophy is already evident. Serial radiographs showed cessation of bone destruction before and evidence of healing since, the graft was inserted

before it is attempted Bone destruction proceeding at a higher level will impair the locked stability of the graft and may cause it to be loosened displaced or fractured (Fig 317)

The close proximity of the sciatic nerve is a bogey which has frightened surgeons including the writer into carrying out the operation by a posterior approach so that the nerve may be seen and protected beyond a period enture One's satisfaction with this security is markedly tempered by the extreme difficulty of keeping the graft and the two femoral fragments in stable apposition when once the support of the soft tissues behind the trochanters has been interfered with In actual fact if the operation as described by Brittain is carried out with due care the risk to the sciatic nerve is exceedingly small

The usefulness of the operation is, of course not confined to cases of inflammatory

disease of the hip It is a relatively less taxing procedure for the elderly patient with degenerative arthritis though the period of immobilisation afterwards is as long as with the intra-articular method The combination of a fibular ischio-femoral graft *inserted (without an osteotomy) through a hole in the femur* together with the introduction of a tri fin nail across the hip joint without erasion of the joint surfaces is a method which has been tried with some success and which offers hope of reducing somewhat the period of immobilisation

The after treatment of the ischio-femoral arthrodesis does not differ materially from that described above The proportion of sound fusions is satisfactorily high and the grafts show a most propitious tendency to hypertrophy rapidly into robust and competent weight-bearing buttresses

ARTHRODESIS OF THE KNEE

INDICATIONS

In the knee also degenerative arthritis constitutes the commonest indication for arthrodesis, though certain differences, attributable to the different structure of the joint are worth consideration In the hip a high proportion of cases comes under the heading of malum coxae senilis, and no very definite trauma can be blamed. In the knee many more cases are explainable on a traumatic basis for the simple reason that it is overtly at least far more susceptible to trauma The number of torn menisci removed bears witness to this More significant is the repeated minor trauma inevitably suffered by the knee that is lax from ligamentous strain Even the normal knee is a lax joint compared with the hip and more of its stability depends on muscles The ball-and-socket structure of the hip is inherently the more stable of the two

This difference probably also explains the observable difference in the painfulness of the arthritic hip and knee How many patients refer jokingly to their creaky knees? Few indeed joke about their arthritic hips The latter joints are tight, seized up often emitting, on movement audible creaks reminiscent of a tight wooden peg turning in its hole there is no escape from the grinding discomfort but in immobility The arthritic knee however wobbles on its way more comfortably; relaxed in sleep its surfaces fall apart somewhat, relieving pain (Fig 318) Not so the clamped hip whose owner sees so many dawns How much more painful is the relatively more rigid knee where degenerative arthritis has followed upon rheumatoid. The thickened synovial membrane and capsule, after years of inflammatory change do not allow that merciful relaxation.

METHODS OF ARTHRODESIS

There is of course no extra-articular arthrodesis for the knee Ankylosis may be promoted by external means but arthrodesis is intra-articular

Many methods are in use but the essential is the removal of the joint surfaces, whether by a sculptured erasion following the condylar contours or by an excision with the saw called by some old-fashioned Whatever the method of erasion it is in the means of fixation that real di culty is seen sliding grafts, latch grafts inlay grafts, complicated H-shaped patellar grafts, crossed grafts pins crossed pins, Kuntschner nails tri-fin nails and so on Such a diversity of methods is usually

testimony to the inadequacy of most of them but in truth the knee is not a difficult joint to fuse and the individual surgeon will have a powerful inclination to find one good method, the simpler the better and stick to it.

Fig 3 8 A knee joint ripe for arthrodesis.

The writer feels that satisfaction of the ego by the dexterous performance of intricate carpentry has no place here The essentials are accurately-fitting opposed surfaces kept tightly apposed and the simplest way to get such surfaces is to cut them flat with the saw

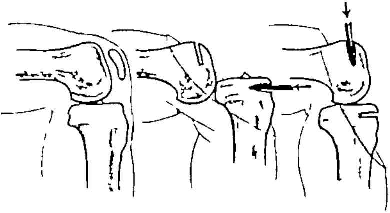

Fig 3 9 Method of displacing tibia on femur and femur on tibia to protect the structures in the popliteal fossa.

Arthrodesis of the Knee with the Tri-Fin Nail

Surgical Approach With the patient supine the knee is approached through an incision beginning in the midline or slightly antero-laterally some 3 inches above the patella, running vertically down to the patella, around its lateral border back

to the midline below it and proceeding vertically down to just below the tibial tubercle The joint is ent red at the lateral border of the patella and laid boldly open up and down in the line of the skin incision

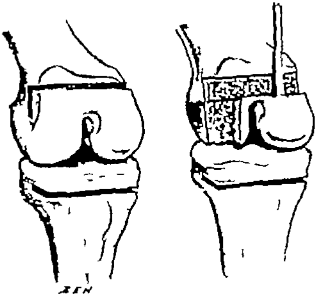

Fig 3 • The saw cuts must stop short of the popliteal vessels and the removal of the articular surfaces is completed with the osteotome

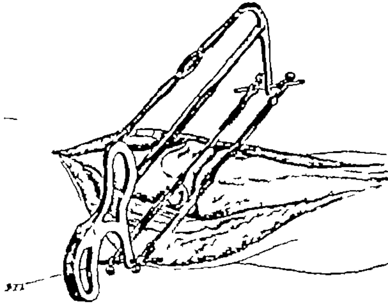

Fig 32 Beginning the removal of the articular surfaces with the double parallel-bladed saw

Technique of Erasion The large flap containing the patella is turned medially di iding or dissecting free the patellar ligament from the tibial tubercle. Remnants of the menisci are removed, the ollateral ligaments divided, cruciate ligaments

carefully divided and dissected away and a careful removal of the unhealthy synovial membrane performed This dissection will allow when the knee is flexed to a right angle the femur to be displaced forwards onto the upper surface of the tibia or the tibia to be displaced upwards in front of the lower end of the femur This is *important as, in* the removal of the articular surfaces from either bone with saw or osteotome the cut can be made towards the other bone and not directly backwards towards the unprotected popliteal vessels and nerves (Fig 319) Owing to the

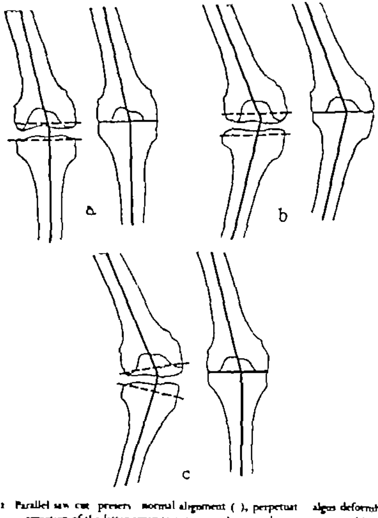

Fig 312 Parallel saw cuts preserve normal alignment ( ), perpetuate algus deformity (*b*), for orrection of the latter separate cut removing wedge are necessary ( ).

position of these structures in the groove between the femoral condyles and in the shallower groove on the posterior aspect of the upper end of the tibia, it is not possible to complete the removal of the articular surfaces with the saw The saw cut must stop short of the popliteal vessels and the *posterior portions of the* articular surfaces are removed with the osteotome keeping clear of these vessels (Fig 320)

Removal of the Articular Surfaces If there is no varus or valgus deformity the proper alignment of the saw cuts is most easily attained by the use of the double parallel bladed saw (Fig 321) If there is such a deformity its correction clearly involves

the removal of a wedge and a parallel-bladed saw is useless In these instances separate saw cuts have to be made (Fig 322) The slices of bone removed are kept as thin as is consistent with obtaining adequate cancellous surfaces in order to minimise shortening of the limb Any such shortening can be still further reduced by packing cancellous chips between the bone ends. Their function here is practically only that of space fillers as the two bones fuse with such readiness that the osteogenic function of the chips is of little practical advantage

The articular surface is now removed from the patella with nibbling forceps as are all remaining portions of articular surface on femur and tibia (Fig 323) A little of the cortex of the front of the upper end of the tibia is removed and this together with the rawed anterior surface of the lower end of the femur provides a surface to which the patella will fuse (Fig 323)

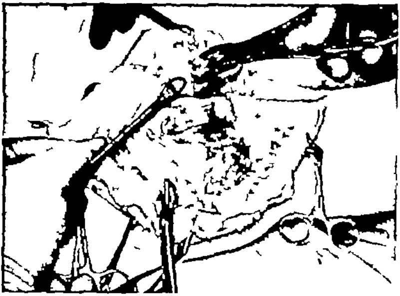

Fig 323 Stamm forceps are convenient for denuding the patellar articular surface Note the accurate apposition of femur and tibia and the rawed bed on the adjacent portions of these bones for the reception of the patella

Introduction of the Tri-Fi Nail All that now remains is the introduction of the nail The cortex of both bones close to the knee is thin and the Watson-Jones guide wire can be pushed straight through with no necessity for gouging out an entrance for it It is necessary that an assistant should hold the foot and leg firmly pressing the tibia against the femur to keep the surfaces apposed. A sandbag behind the knee controls any tendency toward recurvation and the cut bone surfaces can be watched for any tendency to gape in front The guide wire and nail are best introduced, either from above or below along the line between outer femoral and inner tibial condyles If introduced through the opposite condyles the lower end of the nail may damage or irritate the muscular branches of the external popliteal nerve (Fig 324) With the guide wire in position the length of nail can be judged by eye sufficiently accurately or exact measurements of the protruding ends of the guide may be subtracted from its known length (Fig 325) The nail is then

threaded and driven home under direct vision (Fig 326) the guide wire removed and the wound closed (Fig 327)

Fig 324. A nail introduced from inner femoral t outer tibial condyle may imperil muscular branches of the external popliteal nerv

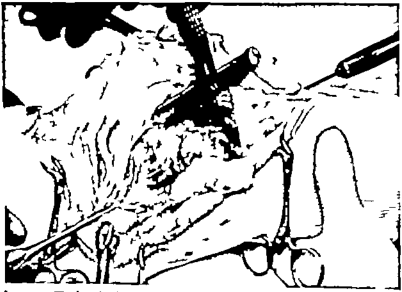

Fig 325 The length of nail required may be judged sufficiently accurately by ey

External Fixation Despite the theoretical necessity for fixing the joint above and the joint below in practice it is found so firm is the fixation by the nail that a

simple plaster cylinder from malleoli to upper thigh is all the external fixation necessary. Nevertheless it is no use asking for trouble and with only this degree of external fixation it is wise to keep the patient in bed for three weeks by which time

Fig 326 The nail is driven under direct vision.

Fig 327 Tri fin nail in place

union will be well started and less reliance need be placed on external fixation. Fusion is usually sound at eight to ten weeks but the removal of the plaster naturally depends on clinical and radiological assessment of each case as does the time when unguarded weight bearing may be permitted.

Complications Apart from damage to the popliteal vessels and external popliteal nerve at the time of operation complications are almost non-existent Failure of fusion is rare and can nearly always be explained by poor technique such as poorly cut surfaces poor apposition a badly-placed nail or too early weight bearing

Other Methods

Sliding Grafts Using the same approach and technique of erasion the two bones can be fixed by means of a *sliding graft Two vertical slightly converging saw cuts* are made on the anterior surface of the femur across the joint and downwards on the anterior surface of the tibia for several inches The bone between the tibial cuts is lifted out and that between the femoral cuts slid down across the joint to engage in the gap left in the tibia (Fig 328) Being wedge-shaped this graft will theoretically at any rate jamb tight The loose portion of tibia can be replaced in

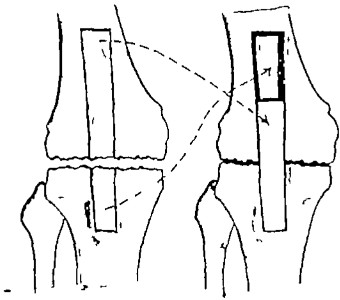

Fig 328 Arthrodesis of knee using sliding graft.

the upper part of the femoral donor area This method calls for painstakingly accurate craftsmanship and even then the cortex that grips the graft is so thin that a very little rocking movement will disengage the graft at one or both ends One has seen this happen so often that the conclusion is inescapable that the fusion which nevertheless almost always occurs does so despite rather than because of the graft A simpler method therefore seems desirable

Crossed Tibial Cortical Grafts (Brittain) The method of H A Brittain using crossed tibial cortical grafts, if properly carried out has abundant theoretical advantages and in fact results in firm fixation Nevertheless it is complicated and its firm fixation can be wrecked by a slight technical imperfection.

Charnley's Method of Firm Pin Fixation Abetted by Tombuckle A theoretical disadvantage of Brittain's method is worth consideration and research in view of the recently published method of Charnley who claims for it the advantage of extremely rapid

union Having excised the articular surfaces almost exactly as described above he employs fixation by means of very firm apposition This is maintained by two pins, passed from side to side through femur and tibia, above and below the joint. Their ends protrude through the skin and are linked on each side of the limb by a special apparatus incorporating a turnbuckle By tightening these turnbuckles daily the firmest apposition can be constantly maintained in the teeth of the rarefaction that is known to occur at the cut bone surfaces in the period immediately after operation. He claims for this method that clinical union commonly occurs in as short a time as six weeks and the total period of disability is reduced to three months

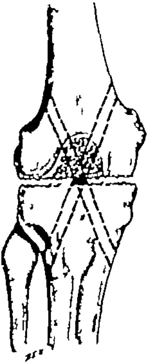

Fig 329 Brittain's crossed grafts lock the cut surfaces firmly together Does this mean they are locked apart when rarefaction takes place ?

While the method is unproven, supporting evidence from other surgeons is already beginning to accumulate and, if ultimately Charnley's contentions are borne out after extended trial it will be interesting to speculate whether despite their firm fixation Brittain's crossed grafts may not actually prolong unnecessarily the time required for union by preventing firm apposition when surface rarefaction occurs (Fig 329) The tri-fin nail method is less open to this theoretical objection as impaction can occur along the nail's axis, by muscular pull guarded weight bearing, or both

Whether or not this method is found ultimately to fulfil its early promise in respect of rapid union it will be attractive to many surgeons when arthrodeses are required for inflammatory disease tuberculous or otherwise since the internal fixation keeps clear of the diseased area Offsetting this advantage are the risk of

sepsis in the pin tracks and the fact that especially in tuberculous disease the contra-indications to the introduction of metal across the diseased area are not absolute The rapid bony union that occurs across most of the excised area is quite often found to outweigh in importance any mild persistence of infection around the metal Provided the latter is removed early the firm immobilisation by the adjacent bony union combined with a judicious avoidance of strains such as weight bearing will usually allow any persisting infection to subside Nevertheless there clearly is a risk in such a procedure and any means of avoiding it will have wide support

Late Results of Arthrodesis of the Knee

Provided that the alignment is satisfactory the results of arthrodesis of the knee are uniformly good. The patient limps, but happily in his freedom from pain Difficulties in tying his shoe apologies for his protruding limb in public transport and the necessity for an aisle seat at the cinema are a price paid cheerfully for painlessness But let there be genu recurvatum worse genu varum or worst of all genu valgum and sooner or later the ankle under unfair wear and tear will begin to complain and an embarrassed surgeon may find himself embarked as it were upon an arthrodesing career

ARTHRODESIS OF THE ANKLE

Once again, by far the commonest indication for arthrodesis is arthritis usually secondary to trauma Paralytic instability is a more frequent indication than in knee or hip since as is well known poliomyelitis so often leaves its major residual paralyses below the knee Slow extrusion, forwards and outwards, of the astragalus from the ankle mortise from weight bearing on an unsupported paralytic varus of the foot is an example still too commonly seen

METHODS OF ARTHRODESIS

There are many methods of arthrodesis of the ankle, each with its earnest advocates but for simplicity ease of performance minimal disturbance of neighbouring gliding surfaces, and consistently good results the writer would, with confidence award the palm to the transfibular method, first developed in the orthopaedic service, of the Royal Air Force by Scott Armstrong and Adams

Transfibular Method

Surgical Approach The incision is made some 5 inches long, vertically downwards over the subcutaneous surface of the lower third of the fibula. It may add to the convenience of the operator to extend the lower end of this incision forwards somewhat in a shallow J (Fig 330) The fibula is exposed subperiosteally and divided about 4 inches from its lower end It is wise to make this division obliquely downwards and inwards to avoid a prominent subcutaneous angle at the lower end of the upper fibular fragment. The lower fragment is now dissected free and laid on one side. Its removal opens a direct approach to the lateral aspect of the ankle joint and this is achieved without any disturbance of tendons and tendon sheaths a fact which must have its influence in shortening the period of post-operative disa-

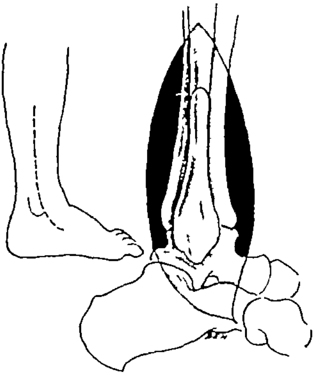

Fig 33 Method of transfibular approach to the ankle joint. Note the oblique line of division of the fibula

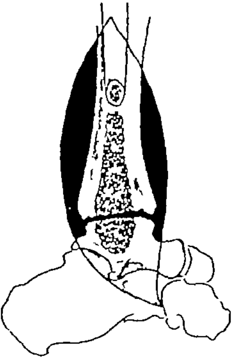

Fig 33 The articular surfaces of tibia and astragalus have been removed and bed prepared for the onlay fibular graft.

bility Apart from gentle retraction of the peronei and the extensors on the anterior aspect of the ankle joint the tendons are untouched

Technique of Erasion and Attainment of Optimum Position The articular cartilages of astragalus and tibia are now erased down to healthy cancellous bone This is most easily carried out with a broad shallow gouge of approximately the same curvature as the joint surfaces except where those surfaces are much distorted and flattened when the osteotome may prove more serviceable

It is important not to allow oneself to become fascinated with the ease of making beautifully parallel cuts in tibia and astragalus Sound fusion alone is not enough There must be no varus of the foot for weight bearing forced onto the outer border

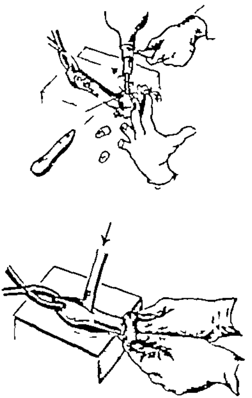

Fig. 332 Unsafe and safe methods of preparing the fibular graft

of the foot is inevitably uncomfortable To avoid this and to obtain the optimum neutral position or at the most one of slight valgus which alone gives a satisfactory plantigrade foot it is usually necessary to remove a slight wedge from astragalus and tibia Indeed, it may be contended that accurate carpentry is rather a waste of time since the gap will be filled with chips which at two to three weeks after operation will have a plastic consistency and a satisfactory alignment can be obtained by moulding with the hands at the change of plaster In practice this proves only partly true Moulding is perfectly possible but it is against the spring of the fibular graft and unless the bone surfaces are cut true a distressing tendency for the foot to spring slowly back into varus even within a plaster will become evident when union has progressed too far for further correction by moulding to be possible

Technique of the Onlay Fibular Graft Before the iliac chips are packed in the cavity the outer aspect of the tibia and astragalus are rawed with gouge or chisel to form a flat bed for the onlay fibular graft (Fig 331) The inner aspect of the fibular fragment is removed to furnish a corresponding raw surface It is safer to do this on a firm sterile wood block with the osteotome than with the motor saw The only safe way of holding the fragment so that it will not spring onto the floor is to take at least one of its ends wrapped in a swab, firmly in the hand under such circumstances the motor saw especially should it catch in the swab holds real menace for the fingers of the assistant (Fig 332)

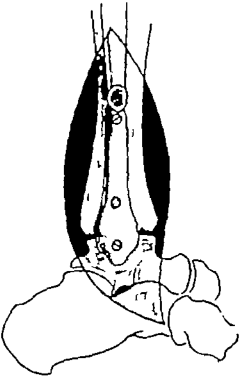

Fig 333 The fibular onlay graft secured with three screws.

With the graft ready chips from the iliac crest are packed into the cavity the graft put in place and secured with three screws, two into the tibia and one obliquely downwards and inwards into the astragalus from the external malleolus (Fig 333) In addition to the correction of any varus deformity already referred to it is necessary to fix the ankle in a few degrees of equinus to allow for a normal shoe heel The wound is closed and the foot and leg encased in an above-knee plaster with the knee slightly bent This is done to avoid any possibility of torsional strain at the arthrodesis. The grip of the single screw in the astragalus is sometimes a trifle precarious and while sufficient to promote fusion in the absence of strain it may not be strong enough to resist rotational strains within a below-knee plaster

After Treatment The plaster is changed at three weeks and the position and alignment checked and corrected if necessary Thereafter a below-knee plaster will

Fig 334 Sound bony fusion of transfibular arthrodesis four months after operation.

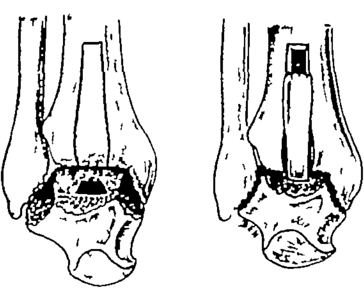

Fig 335 Essentials of arthrodesis of ankle by the method of Watson Jones.

probably suffice The plaster can usually be discarded at about eight weeks and remobilisation of the foot begun even if weight-bearing is not deemed advisable. Union is generally sound by twelve weeks (Fig 334)

Other Methods

The *method of Watson-Jones* using an anterior approach and a reversed wedge shaped graft from the tibia jambed in its own trough with its protruding end embedded in the dorsum of the astragalus, is another excellent method Without going into detail the essentials will be clear from Fig 335 It can be relied upon to achieve sound fusion in the great majority of cases but it is technically more difficult and the route of approach involves a far from negligible disturbance of the structures on the anterior aspect of the joint

A similar type of operation (Brittain) where the graft occupies an intramedullary position in the tibia its channel being cut with a special cranked chisel is open to the same objections though capable of producing excellent results in practised hands

Late Results of Arthrodesis of the Ankle

Sound bony fusion in the optimum position can be relied upon to relieve pain, and so far from the patient being aware of his stiffened ankle he commonly experiences a comforting illusion of enhanced painless movement This is especially so in young people whose flexible feet can develop an astonishing compensatory mobility The writer recollects a young sailor blown up by a mine with a resulting hopeless fracture-dislocation of one ankle and crushed os calcis on the other side who after arthrodesis of the ankle and of the opposite subastragalar joint, could walk and run without a limp point both toes like a ballet dancer and perform a creditable tap dance While subastragalar midtarsal movement is the major mimic of ankle movement in such cases this case with a subastragalar arthrodesis illustrates the part played in regaining mobility by the remaining joints of the foot. One swallow does not make a summer but nevertheless between such results as this and the elderly person whose foot remains stiff but who loses his pain there is a gradation of cases in which the patients will all be grateful to some extent

ACKNOWLEDGEMENT

I am indebted t Sir Reginald Watson-Jones for his kind permission t make free use of clinical material at the Orthopaedic Department of the London Hospital for the illustrations for this chapter

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CHAPTER 26

Bone Transplants in the Treatment of Bone and Joint Injuries

IAN LAWSON DICK

HISTORICAL

THE STUDY of the physiology of the growth and repair of bone began in 1736 with the publication of John Belchier's (1736) historic observation of the pink colouration of the bone of a pig fed on madder This important paper although it occupies only two pages of the Philosophical Transactions of the Royal Society for that year opened an entirely new field of physiological research The fascinating story of the development of the investigation in the hands of Duhamel (1738 1741 1743) Hunter (1837) Syme (1836) Goodsir (1868) Ollier (1868) Macewen (1912) and others should be read by all who are interested in bone graft surgery though it is too long to be told here Only by following the winding path taken by the pioneers can a full understanding of the nature and mechanism of the growth and repair of bone be achieved But the effort is well worth while It is not Wolff's law which an orthopaedic surgeon should cultivate, but a close acquaintance with the behaviour of osteoblasts (Sir Arthur Keith 1919)

Bone transplantation as a surgical procedure was impossible before the introduction of the aseptic principle into surgery Indeed Arbuthnot Lane (1914) early showed that a much higher standard of asepsis is needed in operations on bones and joints than that which is adequate in many operations on the soft tissues Even after Lane's principles were thoroughly understood and accepted however another technical imperfection had to be overcome before bone transplantation could be fully developed It was recognised that grafts should be fixed firmly in position but the lack of a metal suitable for use as an internal suture hindered further progress Grafts failed because wire or catgut sutures or ligatures did not hold them securely enough Grafts fixed by screws failed because the screws loosened or broke

Attempts were made to overcome these difficulties in two ways either by carpentry so accurate that the graft dove tailed firmly into its bed or by the use of a

non metallic fixing device Albee (1941) who probably did more than any other man to establish bone grafting as a standard surgical procedure devised an intricate technique to secure fixation of the graft by exactness of fit. With power-driven tools he fashioned grafts which fitted into the prepared bed with glass stopper precision The accuracy of the fit of the graft had to be such as to render the added fixation of screws or sutures obviously redundant But as anyone with experience of bone grafting knows this is usually technically difficult and sometimes impossible Others attempted to fashion internal sutures of bone—either autogenous bone cut when the graft was cut (Campbell 1923) or heterogenous bone in the form of os purum which is beef bone from which all the organic matter has been removed (Orell, 1937) The use of cowhorn was recommended (Carrell, 1936) Screws made from any of these substances however had disadvantages which a screw made from a suitable metal would not have and none of them came into general use

On September 10 1936 Stuck, Venable and Beach first used vitallium screws as an internal suture for fixing an ivory plate to the femur of a man of 21 They had been searching for a metal which was not acted upon by the body fluids, and vitallium was suggested to them by a dentist who had found it inert in the saliva. After a series of animal experiments they realised that they had found a metal alloy which was non-electrolytic which did not react with the body fluids, which could be removed bright and untarnished years after its implantation Screws could be fashioned from it which did not loosen in bone because of absorption due to chemical reaction around them As will be seen this discovery had far reaching effects on the development of the technique of cortical bone transplantation

PHYSIOLOGICAL CONSIDERATIONS

Behaviour of Transplanted Bone

A large part of the original controversy about bone growth had been concerned with the nature of osteogenesis and long after bone transplantation was introduced there were two views about what happened to transplanted bone Albee (1941) maintained that it lives and grows as a transplanted twig grows in the tree into which it is put. On the other hand Leriche and Policard (1928) Greig (1931) and others affirmed with equal emphasis that a bone graft always dies, and that its only function is to afford a local excess of calcium whereby bone growth is promoted These views are diametrically opposed and quite incompatible and so were the various protagonists much more heat than light was generated in the arguments on the subject[1]

Gradually however sound experimental evidence accumulated and surgeons began to understand the true way in which a bone graft behaves The work of Phemister (1914) of Hey Groves (1918) published in an essay which won him the Jacksonian Prize of the Royal College of Surgeons, of Campbell (1919) of Stuck and Ghormley (1934) and of Ghormley (1942) established beyond reasonable doubt what happens when the whole thickness of cortical bone is transplanted into another bone Some of the cells of the transplant which are near the periosteal or endosteal surface or in the accessible Haversian systems live and grow and form

new bone The bone cells deep in the dense cortical bone di and this bone is replaced by new bone which invades it either from the surviving cells of the transplant or from the recipient area This ingrowth into the transplant of new bone from the recipient area, and the dependence of the transplant on the recipient bone for much of its blood supply explain the need for firm fixation of cortical grafts if they are to succeed

Transplantation of Cancellous Bone

Cortical bone though it is rigid and strong and thus can form a secure internal splint is poorly supplied with bone cells and is therefore feebly osteogenetic If stability of the graft area can be secured by other means it should in theory be possible to take advantage of the facts that cancellous bone contains a much higher proportion of bone cells and is much more readily revascularised Clinical and experimental evidence supports these hypotheses In 1923 Campbell noted that cancellous or endosteal bone is the most osteogenetic type of bone graft, and recommended its use when new bone formation is most necessary as in areas of greatest stress or in bone grafts for non union He supplemented his onlay graft with cancellous bone from the upper end of the tibia which he packed around the fracture site For lumbo-sacral fusion he used blocks of bone cut from the ilium.

In 1931 Gallie of Toronto showed experimentally that cancellous bone had osteogenetic properties much greater than those of cortical bone and ad ocated its use in fractures of the mandible where stability could be maintained by dental splinting and in fusion of the subastragaloid joint and the spine Matti (1932) of Berne in the same year showed in experiments on dogs that cancellous bone chips could produce union across a gap in a fractured femur if the bone was held by a plate Stuck and Ghormley (1934) made an experimental comparison of the osteogenetic proportions of bone transplanted from various sources They showed that of all the known methods of bone grafting that which produced the most rapid and sure new bone formation was the transplantation of cancellous bone chips from the ilium

Interest in this method was reawakened during the last war when intricate and difficult problems in bone repair were frequently encountered and many papers on the subject followed the three presented to the British Orthopaedic Association in April 1945 (Dick, Higgs Robertson) In addition it was soon found that cancellous chip transplants were more resistant to infection than cortical transplants this still further widened the field of usefulness of the method which has now an established place in the treatment by bone grafting of bone and joint disease and injury

INDICATIONS FOR BONE TRANSPLANTATION

1 To promote union in a fracture in which healing is delayed.
2 To bridge a gap in a bone caused by disease or injury
3 To reinforce a weakened bone
4 To help to promote arthrodesis in joints
   (a) By intra-articular grafts
   (b) By e tra-articular grafts

TYPES OF BONE TRANSPLANT

There are two types of bone transplant

1 Cortical bone grafts
2 Cancellous bone grafts

Each of these has its own indications, though as will be seen they may often with advantage be used together

Cortical Transplants

A cortical bone graft has two distinct functions the first of which is by far the more important

1 When it is securely fixed in place it can act as an internal splint.
2 Because it carries live bone cells some of which survive the transplantation it promotes osteogenesis

Cancellous Transplants

The function of cancellous bone transplants is purely osteogenetic The area in which the new bone is to grow from these transplants must be immobilised by some form of splinting either external or internal This splint may be a cortical bone graft a plate a nail or an external splint such as a plaster-of Paris cast. The choice of splint depends on the nature of the technical problems involved

TRANSPLANTATION OF CORTICAL BONE

Seven methods have been described of transplanting cortical bone so that it can be used as a splint Most of these have now been abandoned and they will be only briefly described

1 THE INLAY GRAFT

This is the method (Fig 336 *a*) originally described by Albee (1917) he remained a strong advocate of it until he died A bed is cut in the recipient area with a twin-bladed saw The interval between the saw blades is then increased by the width of two saw cuts and a graft is fashioned which fits the bed exactly with glass stopper precision This may be technically difficult if the fragments are much displaced and because of alteration in the texture of the bone in the neighbourhood of an ununited fracture the bed may not grip the graft firmly Another disadvantage to which further reference will be made, is that intact tibia is cut to provide the graft This method is now less frequently employed than it used to be.

2. THE SLIDING INLAY GRAFT

A bed is cut across the fracture site with a twin bladed saw so that two thirds of it lies on one side of the fracture and one third on the other (Fig 336 *b*) The graft is removed and replaced so that the longer segment lies across the fracture site; the shorter is used to fill the gap It is obvious that this graft cannot fit the bed snugly—it must be narrower than the bed by the width of two saw cuts Albee overcame this difficulty by cutting a sliver graft with which to wedge the main graft in its bed Kelly (1923) suggested that the bed and the graft be fashioned in the shape of a wedge (Fig 336 *c*) Neither of these methods affords rigid fixation however and both are technically difficult

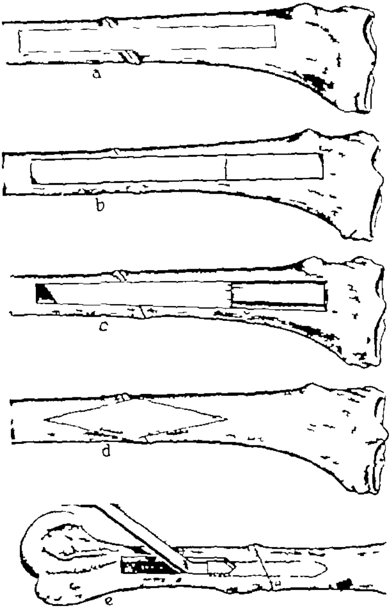

Fig 336.

a, Inlay graft Note the loose fit of the graft in its bed
b Sliding inlay graft Note the gap, equal to the width of a saw cut, between the bed and the graft on either side
Kelly modification of the sliding inlay graft
d Diamond inlay graft (Gallie)
e, Intramedullary peg graft (Hoglund and Hey Groves)

In the tibia one great ad antage of the sliding inlay graft on its parent the inlay graft is that the operation is confined to the fractured bone and the tibia of the opposite limb is not cut Further now that vitallium screws are available, mechani

cal stability can be secured without using either of the less satisfactory methods described above Thus there is still a place for the sliding inlay graft in the treatment of non-union

3. DIAMOND INLAY GRAFT

Gallie (1931) first described this method (Fig 336 d) A diamond-shaped piece of bone, 4 to 5 inches in length is cut from the fractured bone so that the wide piece of the diamond is opposite the fracture site A diamond of cortical bone is cut to pattern from the opposite tibia and slotted into the prepared bed. This method has the advantage of removing most bone from the fracture site where there is most sclerosis Its disadvantages are

(a) The technical difficulties are considerable
(b) There is little or no mechanical stability
(c) The uninjured tibia is cut

It is not in general use and is not recommended

4. INTRAMEDULLARY PEG GRAFT

This method (Fig 336 e) was originally described by Hoglund (1917) and was advocated by Hey Groves (1921) A peg is cut from the cortex of the bone adjacent to the fracture or from the tibia and threaded into the medullary canal across the fracture site This method has several disadvantages The mechanical stability of the internal fixation is inadequate rotation strains in particular being quite uncontrolled there is little opportunity to remove sclerosed bone and open healthy cortex and the revascularisation of the fracture site is impaired by the plugging of the medullary cavity If intact tibia is used to fashion the peg as is sometimes advocated, another disadvantage is added 'The use of the intramedullary peg graft is not only to be deplored but condemned (Campbell 1939)

5. MASSIVE ONLAY GRAFT

Hey Groves originally described this method in 1918 (Fig 337) It was later adopted and popularised by Henderson (1923) and Campbell (1939) The fractured ends of the bone are exposed and all the intervening scar tissue is excised the displacement is reduced and the alignment is corrected if necessary Sclerosed bone and fibrous tissue are cleared from the medullary canal A bed is cut on one aspect of the fractured bone so that fresh healthy vascular bone is widely opened, and a flat surface is formed to which the tibial graft can be applied The graft is firmly fixed to that surface with its endosteal side next to the host.

When the method was first described fixation of the graft was secured by bone pegs either autogenous or homogenous—a part of the technique that was time-consuming and difficult Alternatively the graft could be attached with ligatures of catgut or wire but this function was much less secure In spite of these drawbacks Sir Harry Platt (1938) reported favourably on the method and emphasised its value in gap fractures He pointed out that it was easier to perform in these injuries than Albee's method. He speaks of the inlay graft and the onlay graft as the two standard methods of insertion of a bone graft that are of proved value and prophesied that the onlay technique seems likely to be adopted more frequently in the future

The forecast was accurate. Now that vitallium screws are available, fixation is easily secured, the technical problems are minimal, and the method is the easiest and most effective way of using a cortical bone graft. Its only disadvantage is that usually intact tibia is cut to provide the graft. Its advantages are

(a) A large graft gives very firm and powerful fixation
(b) There is contact between the graft and the host bone over a wide area
(c) The most osteogenetic part of the graft is fixed to the bed
(d) Healthy bone in the host is widely opened offering an early and free blood supply to the transplant

Success with the method is very sure and it is now generally used for cortical bone transplants. Some points of technique are therefore more fully discussed

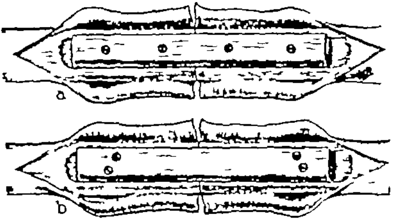

Fig 337

Massive onlay graft fixed with four screws properly placed
b Screws placed near to each other in the graft do not afford mechanical fixation as firm as possible

Technique of Massive Onlay Grafting

Any displacement is reduced. The fibrous tissue is excised from between the bone ends and the medullary canals are opened (Fig 338 *a*). A wide flat bed is prepared to receive the graft. This should be cut with a chisel with the bevelled side nearest the bone. A power driven saw should not be used because of the danger of devitalising the bone surface by burning, though it may be convenient to use the saw to start the cut or to demarcate the bed, especially on the outer aspect of the tibia.

The choice of the surface of the bone to which the graft is to be applied should depend on what covers the surface and not on its accessibility. For example, the outer aspect of the tibia should always be used in preference to the antero-medial surface. Though the latter is the more accessible it is covered by skin only; the outer surface is covered by a mass of vascular muscle (Fig 338 *b*). The choice of site of the bed for the graft in the forearm bone is influenced by similar considerations. In the femur or the humerus the site can be that which is mechanically most convenient since vascular muscles surround the shaft of these bones.

The graft should be firmly fixed to the bed by not less than four vitallium screws, two in each fragment The endosteal surface of the graft is next to the bed and the cancellous bone should not be cut off It forms a compressible cushion between graft and bed and promotes closeness of fit While the screws are being driven the graft is held in place by suitable clamps—Hey Groves bone-holding forceps with clamps fitted to the handles are the most convenient (Figs 339 and 340) Nothing

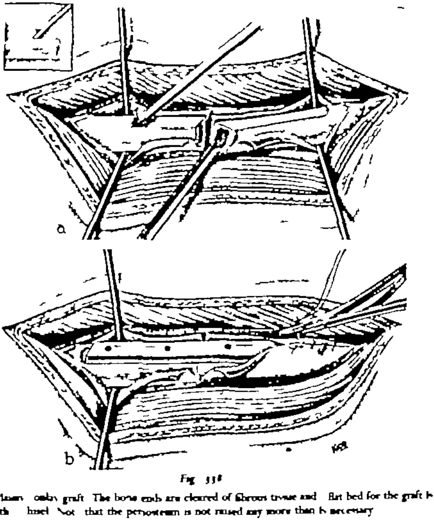

Fig 338

Massive onlay graft The bone ends are cleared of fibrous tissue and flat bed for the graft is cut with chisel Note that the periosteum is not raised any more than is necessary

b The graft should be surrounded by vascular muscle

less than complete mechanical rigidity of fixation should be accepted If for any reason a gap must remain it should be packed with cancellous bone obtained from the head of the tibia or the crest of the ilium

The four screws should be widely spaced along the graft and not placed close to each other at one end (Fig 337 *a*) Two screws close together (Fig 337 *b*) give little more mechanical fixation than one screw The screws should be of the Sherman type that is to say of even diameter in their whole length, and not tapered like wood screws They should be self tapping, with three flutes cut in the end. Three

is the number of flutes which has been shown to reduce to the minimum the torque necessary to drive the screws and the flutes do not reduce the holding power (Venable and Stuck, 1949) The screws are driven into holes previously drilled to a

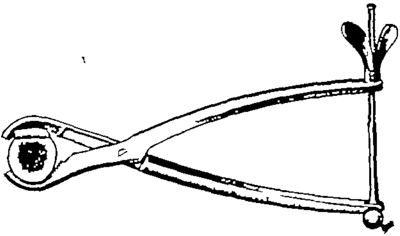

Fig 339 The graft is firmly held by clamps compressing the endost l surface on to the bed.

size equal to the root diameter of the screw Thus the hole for the usual $\frac{1}{8}$ inch screw is made with a $\frac{1}{11}$ inch drill If the drill is too large the screw does not hold if the drill is too small the bone may be fissured and again the hold is impaired

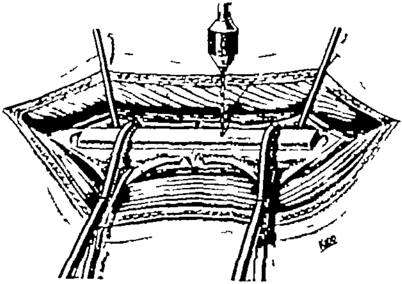

Fig 34 The graft is held by tw Hey Groves clamps while the screw holes are drilled and the screw ar driven.

While the screws are being dri en the graft must be held firmly clamped to the bed or the driving of the screw through the tapped hole in the graft tends to separate the graft from the bed This tendency can also be overcome by drilling the

hole in the graft to a diameter equal to that of the stem of the screw so that the graft is held by the screw head only and not by the thread

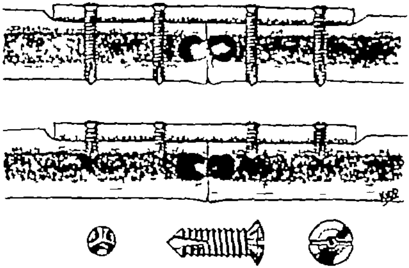

Fig 34 Screws should be of even diameter and self tapping: Sherman type They should engage both cortices of the grafted bone, as in the upper drawing If one only is engaged (lower) the grip is less than half as secure possible

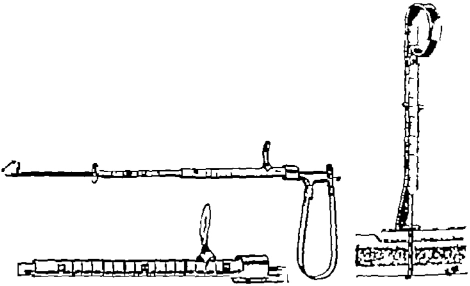

Fig 34 Modification of Adams instrument for measuring screw length Right Adams original instrument in use

The screws should be long enough to engage both cortices of the recipient bone else the hold not as firm as it can be (Fig 341) On the other hand, they should not project far through the bone In the forearm, projecting screws may interfere with rotation by encroaching on the interosseus membrane and in the thigh they

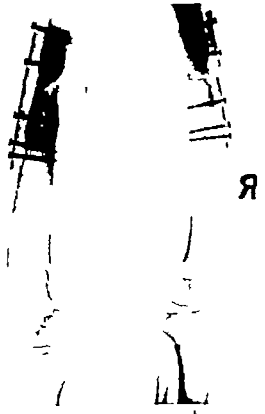

Fig 343 Badly done femoral graft which broke even in plaster

Fig 344

b Failed onlay graft of radius; too short too slender poor fit and insecure fixation

d The same radius fixed with graft of adequate size well secured and with the gap packed with cancellous bone Union at [illegible] weeks.

may interfere with vessels or nerves A patient who had had a bone graft fix his femur with screws which projected ¼ inch beyond the back of the bone afflicted with crippling sciatica which was cured only by removal of the offe screws Vitallium screws which are of the correct length however can be indefinitely in the bone without causing trouble The necessary length of screw can be measured with a suitable instrument after the hole is bored (Fig There are many types of instruments for the purpose that modified from one de by Adams (1943) is probably the most convenient

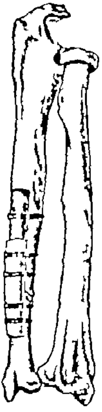

Fig 345 Massive sliding onlay graft of ulna.

Figures 343 and 344 show two bone grafts which failed because of erro technique The graft on the femur (Fig 343 a) although it is of adequate does not fit the bed closely and it is clearly holding the bone under stre fractured in plaster at about ten weeks (Fig 343 b) Figure 344 shows an c graft of the radius which had no hope of success The technical errors are

(a) The graft is too slender and too short
(b) It is not closely applied to the bed
(c) The screws are too close together (as indeed they must be in a graft of size)
(d) The graft is fixed to one fragment by one screw only the second screw not engage the radius

The fracture was later fixed with a graft of adequate size closely applied to the bed and firmly screwed home The una oidable gap in the radius was packed with cancellous chips from the ilium Union was firm in three months (Figs 344 c d)

Two special types of onlay graft need individual mention

6 MASSIVE SLIDING ONLAY GRAFT

This method (Fig 345) is comparable with the sliding inlay graft. Though it was originally described by Gill (1932) it was little used until Vitallium screws became available and even now it is of limited applicability It is particularly suited to the forearm bones It cannot be used in the femur or the humerus because of their cylindrical shape but it can be used in the tibia It does not afford such solid fixation as a tibial onlay graft, however and the only real advantage of this method is that

a *b* *d*

Fig 346

b Un united fracture of lower third of tibia.

d Union secured by onlay graft cut from upper fragment of the same tibia. The bed from which the graft was cut can be seen.

tibia of a sound leg is not cut When the fracture is low in the tibia (Fig 346) a better method of a oiding damage to the sound tibia is to cut the onlay graft from the upper part of the shaft of the fractured bone This graft has the advantage that it is composed of healthy bone cut from the most osteogenetic part of the tibia and not bone of altered texture cut from the damaged area. The donor site consolidates during the period of splinting necessary to secure union of the fracture

7 TWIN ONLAY GRAFT

The problem of securing union in the so-called congenital pseudarthrosis of the tibia was one which taxed orthopaedic surgeons to the utmost Because success was so rare with any of the standard methods of bone-grafting it was considered that some malign influence interfered with the healing of this particular fracture and

many doubted if it was a fracture Yet no abnormality could be found in the blood chemistry there was no apparent hereditary influence and the children were otherwise healthy Only comparatively recently it was recognised that there was no mystery union failed for the simple reason that immobilisation was inadequate Two factors contributed to the failure of the immobilisation Firstly it is next to impossible to immobilise the plump and elastic limbs of an infant or a young child securely by any form of external splint, Secondly the bone to be fixed is so slender and the fragments because of their conical shape are so unstable that to fix them securely with a single plate or graft is not mechanically possible How difficult the

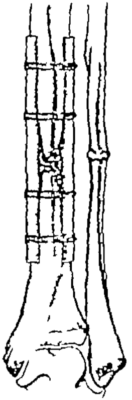

Fig 347 Twin onlay graft with cancellous bone packed into any unavoidable space.

problem was is evidenced by the fact that Henderson (1941) reported 11 cases with only 4 successes

In the same year Boyd showed how by means of vitallium screws and twin onlay grafts solid fixation could be obtained The grafts are placed one on either side of the fragments of tibia and are fixed to each other by vitallium screws These also if possible transfix the tibial fragments Any gaps which are unavoidably left are *packed with cancellous chips either from* the ilium or from the upper end of the tibia (Fig 347) This is *most* important Emphasis should be placed on this step As much cancellous bone as is feasible should be packed about the grafts and the fracture sit (Campbell 1939)

When the patient is old enough that is to say after the age of 6 years or so the

a b c d

Fig 348

b Gap fracture of tibia due t osteomyelitis.
d Union secured by twin onlay grafts, onlay grafts obtained from patient sister

a b c d

Fig 349

b Defect of tibia due to infected open fracture
d Tibia reconstructed with twin onlay grafts from other leg and cancellous chips.

twin grafts can be cut from the other tibia before this age a parental or a sibling donor is needed in order to get enough bone The grafts should be cut in the manner described on page 542 and the crest of the tibia or most of it should be

retained so that the bone is not too severely weakened. It is of great advantage to have two operating teams working simultaneously as even under these conditions the tourniquet has to be left on the fractured leg for rather a long time.

Beds are first prepared on either side of the pseudarthrosis Twin grafts are then cut from the donor to the required length (measured with a caliper) and applied one on either side of the recipient bone with the endosteal surfaces inwards They are held in position with Hey Groves clamping forceps and secured by four screws which engage both cortical grafts and if at all possible the slender recipient bone as well Packing of the whole area between the sandwich with cancellous chips completes the reconstruction

Figure 348 shows an un-united gap fracture of the tibia, the result of osteomyelitis of the shaft of the bone with extensive sequestration. In three months union was firm enough to discard the plaster-of Paris splint and allow remobilisation of the joints In this instance the twin onlay grafts were obtained from an elder sister Figure 349 shows the reconstruction of a tibia in which there was a large gap fracture caused by a grossly comminuted infected open fracture of the bone sustained in an aircraft crash The twin grafts were obtained from the other tibia. A

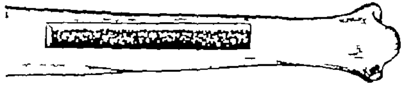

Fig 35 Bed from which small inlay graft was cut from antero medial surface of tibia.

stress fracture developed in the donor tibia at eight weeks, and in the end the reconstructed tibia was taking the body weight without external support six weeks before the donor tibia could be trusted

DONOR SITE

The tibia is almost always used to provide the massive onlay graft because it is of suitable shape it is readily accessible and the cortex is strong When a small bone graft is wanted, say $\frac{1}{2}$ by 4 inches for grafting a forearm bone it can easily be taken from the middle of the subcutaneous surface of the tibia (Fig 350) When an exceptionally powerful graft is wanted the whole of the subcutaneous surface of the tibia may be removed as recommended by Brittain (1942) This graft consists of the entire antero-medial cortex of the tibia including the crest and it is very strong but it should seldom be used as it unduly weakens the tibia It may occasionally be needed when twin onlay grafts are required, but even then most of the crest can usually be left A better method of cutting a powerful tibial graft is shown in Fig 351 One longitudinal saw cut is made on the medial surface of the tibia. This cut is difficult to make and great caution must be exercised to see that the stockinette or skin towels do not get entangled in the saw The second longitudinal cut is made on the antero-medial surface as near to the crest as necessary or even through the crest but as much of the crest as possible should be preserved. It is important that

the saw cuts should be complete and that the graft should be simply eased out of its bed with an osteotome not cut out with hammer blows If the graft is hammered out a fissure can be produced which may be the starting point of a stress fracture The periosteum should be sutured in order to limit the haematoma in which the bone is reconstructed When a graft is cut out of the middle of the cortex apposition may be difficult to secure because of the elastic retraction of the periosteum When the inner edge of the graft is cut through the medial cortex of the tibia this difficulty does not arise

Complications at the Donor Site

1 *Stress Fracture* This may follow the removal of any tibial graft In this patient it developed eight weeks after the removal of a graft by the method shown in Fig 351 In Fig 352 *a* the crack can hardly be seen (it is difficult to see it even in the original skiagrams) but the history was typical Sudden acute pain developed in the

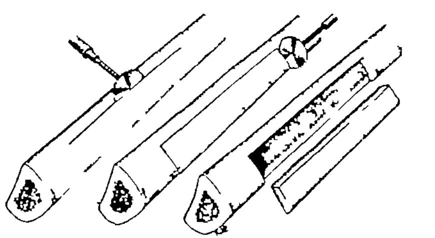

Fig 351 Recommended method of cutting powerful cortical graft from tibia. The crest is *not removed*

leg whilst the patient was walking on enquiry she admitted to having had slight but increasing pain in the leg for a few days previously (It is always well to warn patients of the possible significance of the onset of pain in the donor leg) The leg was immobilised in a walking plaster and the subsequent development of callus at the fracture site put the diagnosis beyond doubt (Fig 352 *b*)

As has been stated, this complication may follow the removal of any graft from the tibia and the fact that only a small portion of bone is removed is no guarantee that the tibia will not give way Armstrong (1945) reports two instances of stress fracture of the tibia after removal of pegs for grafting the carpal scaphoid Stress fracture of the tibia in these circumstances must be due to damage to the lamellar structure of the bone rather than to reduction of its total bulk, and its occurrence indicates that *it is never completely* safe to cut an intact tibia For this reason as well as for that of avoiding the use of two tourniquets when one would suffice the tibia of the same limb should be used for femoral grafts This may be less convenient if two teams are operating simultaneously but the donor tibia, as has already been

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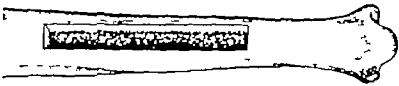

Fig 350 Bed from which small inlay graft was cut from antero-medial surface of tibia.

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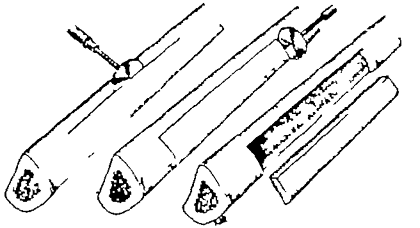

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mentioned has an opportunity to recover during the period of post-operative splinting

2 *Painful Donor Site* This complication is less often written about than stress fracture and is probably therefore less well known, but it is more common. The pain may be very troublesome and persistent and many patients complain of pain in the donor leg long after the grafted leg is healed and symptomless While therefore, it may be necessary to use a cortical graft from an intact tibia, especially for the femur or the humerus, every consideration should be given to the possibility

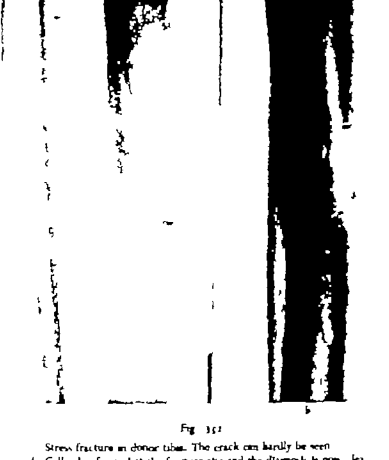


Fig 351

Stress fracture in donor tibia. The crack can hardly be seen

b Callus has formed at the fracture site and the diagnosis is now clear

of obtaining the desired result by other means before the decision is taken While serving as orthopaedic consultant in the Royal Air Force Osmond Clarke said, the more I see of the results of bone grafting, the more I become loath to mutilate an intact tibia

TRANSPLANTATION OF CANCELLOUS BONE

The two functions of a cortical bone transplant in bone repair are to provide stability and to promote osteogenesis When it is properly used it performs the first of these functions well It performs the second with less efficiency Cancellous

bone transplants have now an accepted place in the surgery of bone repair because of their osteogenetic properties

INDICATIONS

The indications for the use of cancellous bone transplants may be stated as follows

1 When a gap in a bone has to be bridged the *form of the bone is maintained by* a rigid cortical graft or a plate and the gap is packed with cancellous bone chips

2 Often in the arthrodesis of joints it is difficult to get close bone-to-bone apposition after the joint has been excised It I well recognised that close approximation of the bone surfaces so that no gap is left in which fibrous tissue can form is an important factor in obtaining bony fusion This is particularly so in the hip

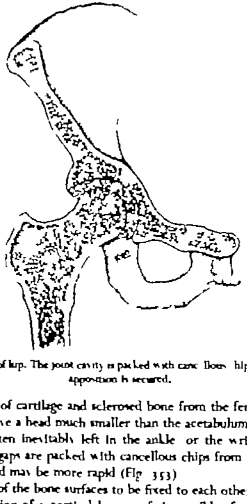


Fig 353 Arthrodesis of hip. The joint cavity is packed with cancellous chips so that bone to bone apposition is secured.

where the excision of cartilage and sclerosed bone from the femoral head and the acetabulum may leave a head much smaller than the acetabulum which *contains* it Similar gaps are often inevitably left in the ankle or the wrist—indeed, in any joint When these gaps are packed with cancellous chips from the ilium, fusion is much more sure and may be more rapid (Fig 353)

The irregularity of the bone surfaces to be fixed to each other may be such as to make the close fitting of a cortical bone graft impossible for example *in* extra articular arthrodesis of the spine (Fig 354) or in lumbo-sacral fusion. Similarly in intra-articular arthrodesis of small joints like those of the tarsus, in particular the subastragaloid joint or of the carpus or metacarpus in particular the carpo-metacarpal joint of the thumb cancellous chips are most convenient because of the ease with which they can be packed into a small and irregular cavity

3 Cancellous bone grafts are much more resistant to infection than cortical grafts and can be used with safety where cortical grafts would fail This observation was first made by the plastic surgeons who used the iliac crest for reconstruction of

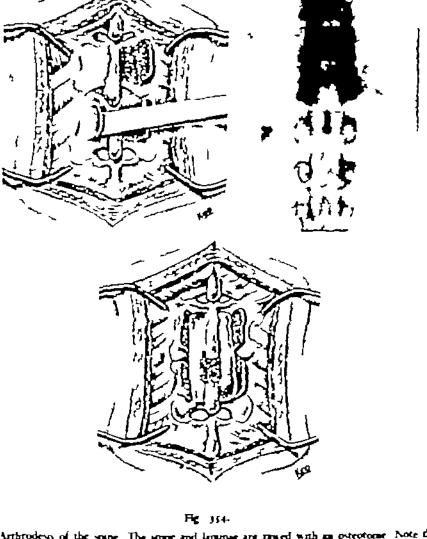


Fig 354.

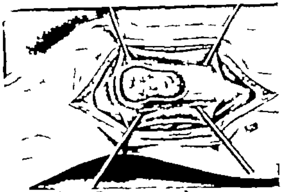
a, Arthrodesis of the spine The spine and laminae are rawed with an osteotome Note the hole in the spinous process left by the localising screw. This is inserted at an early stage of the operation and the vertebra is identified by an -ra on the table (*b*)

Blocks of iliac bone and cancellous chips from the ilium are packed alongside the rawed surfaces

the jaw The original reason for its use here was its shape Many of these fractures are actually or potentially infected, however and it was soon realised that cancellous grafts could withstand infection in a way that cortical grafts could not. This observation has since been confirmed many times, and it is now generally accepted that the

possibility of infection in the graft area does not mean that cancellous grafts cannot be used although a cortical transplant would be unsafe and unjustified

Fig 355



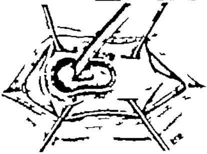


Fig 356

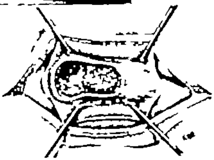


Fig 357

Fig 355 An osteoclastoma of the lower end of the femur is exposed by removal of the overlying cortex.

Fig 356. The tumour material is removed and the cavity is carbolised.

Fig 357 The cavity is packed with cancellous chips.

b

Fig 358

An osteoclastoma of the os calcis.

b Ten weeks after excision and packing with cancellous chips (Mr A. Naylor case.)

4. The filling of a gap in a bone left by the excision of an osteoclastoma, an enchondroma or an area of osteitis (Figs 355 to 359) This last is of particular importance and interest It has been made possible in a large part by the development

of chemotherapy but it is also evidence of the resistance of cancellous bone chips to infection (Robertson, 1941)

5 Their use in restoration of facial contour though it is important and valuable does not come within the scope of this article

a *b*

Fig 359

A st of the mid shaft of the humerus.

b Ten week after excision and packing with iliac chips. (Mr A. Naylor s case)

OPERATIVE TECHNIQUE

Figure 360 shows that the two accessible areas of the ilium where cancellous bone is most abundant are (1) below the crest just behind the anterior superior iliac spine and (2) at the posterior aspect of the ilium in the region of the posterior superior

iliac spine Of the two donor sites the latter provides by far the greater quantity of cancellous bone and it should be used whenever possible if a large amount of bone is needed.

Anterior Donor Site

It is convenient to make the ilium prominent by putting a small sandbag under the buttock of the same side The crest of the ilium is exposed and turned up as a lid. The cancellous bone can then be cut from between the tables of the cortex with a hand gouge (Fig 361) If more cancellous bone is needed than can be obtained in this way a window can be turned down on the outer aspect of the bone Unless there is danger of infection in the recipient area the cortical bone can be included

Fig 360 The two accessible areas in the ilium where cancellous bone is most plentiful

in the chips It is very thin and much more vascular than the cortex of the long bones The crest should be preserved in order that the normal contour of the hip girdle may be retained—this is of more cosmetic importance in women Latterly I have been turning down a window in the outer cortex as a routine (Fig 362) By this means muscle is brought into contact with the bleeding bone surface and haemorrhage is arrested. This change of technique was prompted by the occurrence of several haematomata in wounds from which cancellous bone had been cut from between the tables of the iliac cortex

Posterior Donor Site

The neighbourhood of the posterior superior spine of the ilium is a much more plentiful source of cancellous bone than the anterior crest, and it should always be

chosen when a large amount of cancellous bone is needed Fortunately it is conveniently accessible in fusion of the spine or the lumbo-sacral area in which more

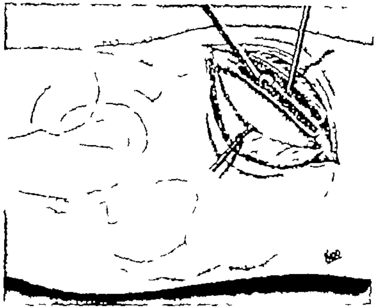


Fig 36 Method of cutting cancellous chips from the anterior crest of the *ilium*.

cancellous bone is needed than in most *operations The best way to obtain the* grafts is to make a subperiosteal *exposure of the posterior superior spine of the* ilium and the *posterior crest. The posterior end of the crest is then removed in a*

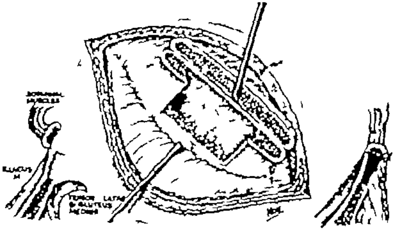


Fig 36 *If a window is* cut in the outer table more cancellous bone is made accessible and muscle when it is replaced comes in contact with the bleeding bone surface (see inset).

block (Fig 363) This block, when cut in two longitudinally provides two grafts which lie con*veniently one on either side of the spinous processes as in fusion of the* spine Alternatively *the block can be cut up into chips of convenient size* A

further quantity of chips can be gouged out of the thick cancellous bone which has been exposed

It is convenient to have *a board with a low rim* around the sides of it on which to cut up the cancellous bone; this is readily done with an osteotome or with a stout pair of scissors The size to which the chips should be cut varies according to the size of the cavity to be filled In general the smaller they are the more *tightly they* can be packed, and although difficult to prove it seems likely that tight packing of the chips helps to promote union They should be packed in with a broad blunt instrument like a punch and from time to time a gauze swab should be pressed down firmly on the surface being packed This absorbs the juice expressed from *the bone chips so that the* operator can more readily judge when the cavity is well enough filled

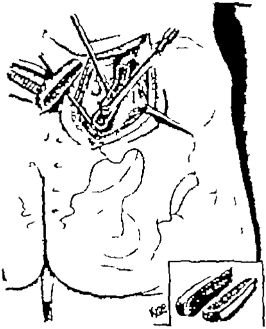


Fig 563 Method of obtaining block of cancellous bone and cancellous chips from posterior donor sit

Need for Prolonged Immobilisation

It is well known that bone grafts must be protected by external splinting, usually plaster-of Paris while they are consolidating, and that this process usually takes from eight to twelve weeks It must be emphasised that this *period can be given* only as an approximation and that the progress of the consolidation of each graft must be watched and judged by clinical and radiological standards *It is inadvisable even to test cortical grafts for union at less than eight weeks* and union should not be accepted as solid until there is definite radiological evidence that it is so The graft must be obviously fused with the host in its whole length, and though the fracture line may still be seen there should be trabecular continuity across it.

Perhaps even greater care is needed with cancellous chip grafts They fuse so rapidly in the early stages that it is not uncommon for say a knee joint which has been excised and packed with cancellous chips to be clinically firm when the post

operati e plaster is changed at fourteen days To accept this clinical firmness as union would lead to disaster In a very few days the knee would be mobile again and unless external splinting was at once resumed and continued until there was radiological evidence of consolidation the iliac chips would disappear by absorption.

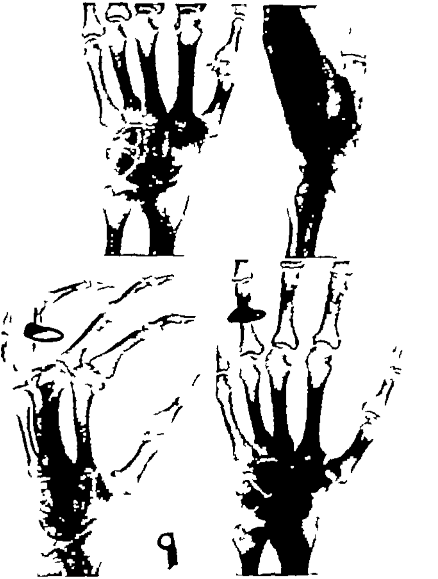


Fig 364.

Upper This carpo-metacarpal fusion was considered to be solid at four weeks.
Lower The splint was discarded and movement was allowed the chips were absorbed.

Although cancellous chips become firm quickly there is reason to believe that they do not consolidate any more rapidly than cortical grafts and it can seldom if ever be safe to subject them to strain at less than eight weeks

Figure 364, upper shows the x ray of a fusion of the carpo-metacarpal joint of a thumb at five weeks after operation. Clinically union was quite solid, and this

x ray appearance was regarded as evidence of consolidation and plaster was discarded. A few weeks later the patient began to complain of some pain again at eight weeks there was no doubt clinically that the joint was not stable and x ray showed that a cystic cavity had developed in the fusion area (Fig 364 *lower*) This appearance is exactly comparable with that seen in the fractured scaphoid which has not been immobilised and is due to the same cause namely hyperaemic bone absorption Cancellous chip grafts must be protected till they have consolidated and they certainly do not consolidate in less than eight weeks If the area which has been grafted is once subject to great mechanical stress twelve or sixteen weeks of splinting may be needed before consolidation is secure

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CHAPTER 27

Recurrent Dislocation of the Shoulder

J CRAWFORD ADAMS

THE PROBLEM of recurrent dislocation of the shoulder is encountered rather infrequently in orthopaedic practice Nevertheless it is one which has aroused considerable interest because of the widely divergent opinions which have been expressed on the nature of the underlying pathology and on the principles to be followed in its surgical treatment In recent years the true nature of the pathology has been more widely understood and in consequence of this knowledge it has become possible to select from the many operations available only those which are sound in principle and which are based on a correct interpretation of the pathological anatomy This more rational approach to the problem has been rewarded in practice by the achievement of greatly improved results; so much so that whereas a few years ago the failure rate was sometimes as high as 35 per cent it is now possible to offer at least a 95 per cent chance of lasting relief

Recurrent shoulder dislocation occurs most frequently in young adults particularly among those of athletic habits and in the subjects of epilepsy Except in rare instances the initial dislocation is always of traumatic origin In the overwhelming majority of cases the displacement is anterior in the exceptional case it is posterior There has been much discussion on the relationship of recurrent dislocation to simple dislocation In spite of statements to the contrary the available evidence indicates that there is no essential difference in the mechanism of the injury or in the direction of the displacement in the two types the distinction lies simply in the anatomical site of the injury If this is a tear of the capsule, spontaneous healing is likely to take place and the dislocation will not recur but if the dislocation has been associated with avulsion of the capsule from the glenoid margin, or damage to the humeral head natural repair is liable to be incomplete and stability impaired.

RECURRENT ANTERIOR DISLOCATION

This is the usual type The dislocation is subcoracoid. The mechanism of the injury is most commonly a fall on the outstretched hand Owing to the forward

inclination of the glenoid fossa the force resulting from such a fall is transmitted to the front of the joint and drives the head of the humerus directly forwards over the anterior glenoid margin

PATHOLOGY

Historical Note

The occurrence of a bone lesion of the humeral head in cases of recurrent dislocation of the shoulder was recognised many years ago As early as 1837 an example was reported by Curling from the London Hospital Curling's patient was possibly the subject of epilepsy for eventually he was seized with convulsive fits, became insensible and died in two days. He had applied at the London Hospital on fifteen occasions on account of dislocation of the shoulder which was usually reduced without difficulty In addition he had sustained numerous dislocations which had been reduced spontaneously After his death the shoulder was dissected 'There was a false socket beneath the coracoid process at the inner edge of the glenoid cavity in front of the neck of the scapula, and bounded by the subscapularis muscle The head of the humerus was greatly altered in shape About one fourth of it together with the connecting cartilage had been removed so evenly that the head appeared as if a section had been made of it. This remarkable atrophy was doubtless occasioned by the friction to which the head of the humerus had been subjected in its play from the natural to the false socket, and operated most efficiently as a bar to the bone being subsequently retained in its right situation during the motions of the joint

In spite of its early recognition the significance of the humeral head defect was not widely appreciated It was largely forgotten Surgeons even became sceptical of its existence Attention was focussed instead on other components of the joint on the muscles, on the ligaments or on the capsule This widespread neglect of the bone defect of the humerus was no doubt due to the fact that opportunities for a detailed anatomical study of the shoulder in cases of recurrent dislocation seldom presented themselves either in the living or dead subject. Moreover the bone defect was confused with the secondary bone changes occurring in cases of old unreduced dislocation a relatively frequent condition prior to the last few decades Even after the introduction of radiography as a diagnostic procedure the bone changes were overlooked because they were not shown in the routine antero-posterior projections of the shoulder

The next important stage in the evolution of our knowledge was in 1923 when Bankart claimed that the essential lesion was a separation of the glenoid labrum from its attachment to the bone of the anterior margin of the glenoid. According to his opinion this lesion alone accounts for the tendency to redislocation in every case Bankart did not regard bone changes as being of aetiological significance On the basis of his interpretation of the pathology he described and practised the operation now known by his name

Bankart's views were widely accepted and his work stimulated renewed interest in the problems of recurrent dislocation of the shoulder Nevertheless there were some who could not accept the view that the separation of a soft tissue structure of such small dimensions was the only factor accounting for the tendency to redislocation At the same time the increasing precision of radiographic technique which

facilitated a more detailed study of the joint in various positions of rotation led to a rediscovery of the bone changes of the humeral head. The frequent incidence of these changes was noted. It was realised afresh, as Curling had suggested, that the defect might be a factor in causing redislocation and not merely one of its effects. The significance of the bone changes has been emphasised recently by Hill and Sachs (1940) and by Adams (1948) and Palmer and Widen (1948).

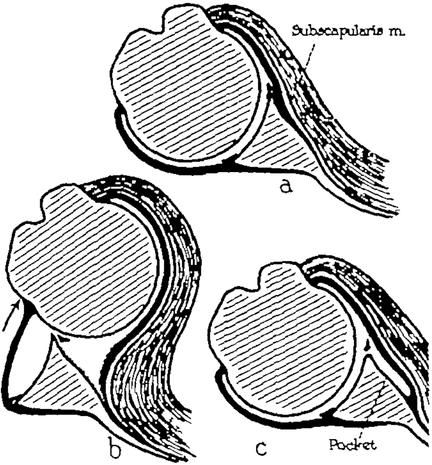

Fig. 365. The soft tissue lesion. Horizontal section through the left shoulder.

Normal condition.

b. Anterior dislocation. The capsule has been stripped from the front of the neck of the scapula; the glenoid labrum has been detached anteriorly and displaced.

c. Incomplete healing has resulted in the formation of a potential pocket between the front of the neck of the scapula and the capsule deep to the subscapularis.

Pathological Findings

It is now widely accepted in Great Britain that the pathology consists of two important elements. These may be described as the soft tissue lesion and the bone lesion.

The soft tissue lesion consists essentially of stripping of the anterior part of the capsule from its broad attachment to the front of the neck of the scapula (Fig. 365).

Associated with it there is usually though not invariably a detachment of the anterior segment of the glenoid labrum from the bone margin of the glenoid The results of these changes are twofold First the effectiveness of the anterior part of the labrum and of the capsule as a bar to forward displacement of the humeral head is lost Secondly a potential pocket is formed in front of the neck of the scapula (the false socket mentioned by Curling) into which the head of the humerus may escape while still remaining within the joint capsule (Fig 365 c) Bankart's view that the detachment of the labrum is always the essential and all-important lesion is no longer acceptable The observation, confirmed in a recent analysis of a large series of cases that detachment of the glenoid labrum is by no means a constant finding at operation forms a powerful argument against such a conception It is agreed that the labral detachment is significant but it forms only part of the soft

Fig 366 The bone lesion Note typical defect of the postero-lateral aspect of the articular surface of the humeral head. (Modelled from specimen seen at operation.)

tissue lesion and it is probable that the stripping of the capsule from the front of the neck of the scapula is of greater significance than is the separation of the labrum itself

The bone lesion consists of a depression or flattening of the postero-lateral aspect of the articular surface of the head of the humerus (Fig 366) The flattened area becomes engaged with the glenoid fossa when the arm is in a position of abduction and external rotation If the arm is extended (i e swung backwards) from this position the deficiency in the contour of the articular surface permits the humeral head to slip forwards out of the glenoid fossa (Fig 367) This mechanical effect of the bone deficiency may frequently be demonstrated at the time of operation and it can be correlated with the clinical observation that it is precisely in this position of abduction external rotation, and extension that redislocations most commonly occur A defect of the humeral head of this type can be shown to be present in more than four fifths of all cases of recurrent dislocation of the shoulder Its true incidence

may well be above this figure because the demonstration of the lesion is difficult both by radiography and at operation Its significance is beyond question although

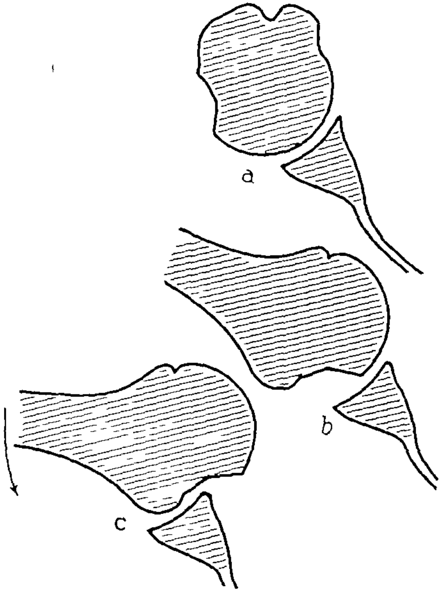

Fig 367 Mechanical effect of the bone defect. Horizontal section of the left shoulder

In the neutral position of the arm the defect lies postero-laterally

b When the humerus is abducted and externally rotated the defect comes into relation with the glenoid fossa.

c, Extension of the arm from this position permits the defective area of the articular contour to slip forwards over the anterior glenoid margin Dislocation results.

It is possible for recurrent dislocation to occur in the absence of a bone defect of the humeral head It is neither so frequent nor so easily produced as is the case when the defect is present

The cause of the defect is a matter which has occasioned considerable discussion It is most probable that it represents the end result of a compression fracture of the articular surface sustained at the time of the initial dislocation (or at a subsequent dislocation) by violent impingement of the relatively soft humeral head against the sharp angle of the anterior margin of the glenoid This view is supported by the evidence cited by Hill and Sachs who detected the lesion radiographically immediately after a dislocation of a shoulder which had been shown to be normal radiographically two months previously Moreover it is readily understandable that the lesion may occur from such a cause in view of the fact that the cortical bone of the humeral head is very thin and its cancellous interior is soft and readily compressed The injury is comparable to the denting of a table tennis ball which would result from its forcible impingement against the sharp edge of a table Though the depression initially may be small it is likely to become enlarged as a result of repeated dislocations

RADIOGRAPHY OF THE HUMERAL HEAD DEFECT

It is a matter of interest and some importance to be able to demonstrate the defect radiographically when it is present. This is by no means easy unless much care is taken in the accurate positioning of the subject for radiography unless the defect is shown in profile it is readily obscured by the overlapping shadow of the humeral head In considering the principles to be followed it must be borne in mind that the defect occupies a position at the postero-lateral aspect of the head of the humerus Its surface forms an angle of 60 to 70 degrees with the sagittal plane when the arm is in the neutral rotational position In order to show the defect in profile in an antero-posterior radiograph it is therefore necessary to have the humerus rotated inwards through 60 to 70 degrees Accurate positioning is essential because an error of 10 or 15 degrees may be sufficient to result in the defect being missed

Radiographic Technique

In practice the most convenient manner in which to obtain the required projection is to have the subject supine upon the examination table the elbow of the affected side being supported on suitable pads which are so adjusted that the long axis of the humerus is parallel with the surface of the table The cassette is placed behind the shoulder The elbow is flexed 90 degrees in order that the forearm may be used as a pointer to indicate the degree of rotation of the humerus The arm is rotated inwards through 65 degrees measured by a protractor (Fig 368) An antero-posterior projection is made the central ray being directed through the upper and outer aspect of the head of the humerus

In radiographs obtained in this manner the defect when present is always seen at the upper and outer aspect of the shadow of the humeral head It is seen either as a deficiency of the convex outline of the articular surface (Fig 369) or as a dense line of condensation extending downwards from the upper part of the articular surface parallel with the shaft of the humerus (Fig 370)

INDICATIONS FOR OPERATION

Recurrent dislocation of the shoulder can be cured only by surgical operation Whether or not this should be advised in a given case is a matter requiring careful

consideration Important factors to be assessed are the number and the frequency of the dislocations the degree of violence necessary to cause dislocation, the radiological findings, and the age occupation, and wishes of the patient No hard and fast rules can be laid down Each case must be considered as an individual problem Nevertheless if four or more dislocations have occurred with increasing frequency and decreasing violence if a large defect of the humerus is detected radiologically or if the patient s occupation is such that a stable shoulder is essential then operation will usually be considered advisable There are definite disadvantages in delaying too long in such a case for after repeated dislocations there is a well-

Fig 368 Position of patient and of apparatus for radiography of the head of the humerus in recurrent dislocation of the shoulder Note forearm held parallel to protractor set at 65 degrees with the vertical plane

marked tendency for degenerative arthritic changes to develop in the joint Moreover successful operative repair is liable to become more difficult owing to progressive enlargement of the humeral head defect and to secondary attrition of the anterior margin of the glenoid

CHOICE OF OPERATION

In planning a rational operation for the cure of recurrent dislocation of the shoulder it is important to bear in mind the significance not only of the soft tissue lesion but also of the bone lesion described above Both are important and both must be remedied or rendered inactive if permanent relief from symptoms is to be

obtained The first lesion, the capsular stripping is clearly amenable to direct repair Not so the second for when a bone defect of the head of the humerus is present it is unfortunately not possible to restore the normal contour of the articular surface This lesion can nevertheless be rendered inactive by preventing its engagement with the anterior margin of the glenoid fossa

In many of the operations which have been described no attempt is made to counter the underlying pathological lesions directly In one group of procedures reliance is placed instead on supporting the humeral head from above by the formation of a new ligament or from below by some type of muscle sling As the dislocation is anterior and not inferior these measures in themselves are unlikely to be successful That the operations of this type are sometimes, in fact successful in restoring stability to the shoulder—at any rate for a time—is probably due in large measure

Fig 369 Fig 37

Fig 369 Typical large defect of the humeral head seen in profile The well-marked deficiency of the articular contour is unmistakable

Fig 370 Typical small defect of the humeral head Note the dense line of condensation extending downwards from the upper part of the articular surface parallel with the shaft

to the scarring of the soft tissues in front of the joint which results from the operation Nevertheless they cannot be relied upon to produce permanent relief and they should be discarded

In another group an attempt is made to bar the forward displacement of the humeral head by the creation of an anterior block This may be of fascia or of bone Such operations are sound in so far as they are designed to counter the effect of the soft tissue lesion the capsular stripping But they do not prevent engagement of the defective area of the humeral articular surface with the glenoid In practice they are successful in preventing further dislocations in a high proportion of cases Nevertheless the continued friction of the irregular roughened area of the humerus on the smooth cartilage of the glenoid is undesirable if only for the reason that it may ultimately lead to some degree of degenerative arthritis with associated pain

The Bankart Operation

A special word is necessary concerning the Bankart operation, a procedure which is held in much favour and which is undoubtedly attended by satisfactory results in a high proportion of cases The professed aim of the operation is to effect the reattachment of the glenoid labrum to the bone of the anterior margin of the glenoid. In practice however this is achieved indirectly by fixation of the medial margin of the capsule (with labrum attached) to the anterior aspect of the glenoid rim rather than by direct suture of the labrum to the bone An important subsidiary effect of this procedure is that the anterior capsular stripping which constitutes the essential feature of the soft tissue lesion is thereby repaired. To this factor rather than to the simple reattachment of the labrum the success of the operation can most probably be attributed. This view is supported by the observation that the operation is frequently successful in relieving the disability even in those cases where the glenoid labrum has been so completely worn away by the attrition of repeated dislocations that its reconstruction is impossible

The Bankart operation does not take into account the effects of the bone lesion of the humerus Moreover it is technically difficult to perform with satisfaction, and a special drill is almost a necessity For these reasons it is giving place among many surgeons to the Putti Platt operation, which embodies a similar principle of repair of the capsular stripping but which provides in addition a satisfactory method of preventing engagement of the defective area of the humeral head with the glenoid fossa Since it gives results which are at least as good as those of the Bankart operation and is at the same time relatively simple in execution, the Putti-Platt operation can be recommended with confidence for general use

THE PUTTI PLATT OPERATION

Origin

The operation was performed by Putti in 1923 though he left it to his pupil Valtancoli to publish a description in 1925 It was developed independently at about the same time by Platt in England. But much of the credit for its general introduction should go to H Osmond-Clarke (1948) who is also responsible for giving to the operation the name used here Because of its rational principles and relati e simplicity it has gained much favour in Great Britain in recent years.

Principles of the Operation

The operation aims firstly to promote the formation of a firm mass of fibrotendinous tissue in front of the anterior margin of the glenoid, obliterating the capsular pocket described above and acting as a barrier against forward displacement of the humeral head. This is achieved by reefing of the capsule anteriorly and of the subscapularis which is at the same time sutured down to the region of the front of the scapular neck (Fig 371) Secondly it aims to limit the last few degrees of external rotation and extension of the humerus, thereby preventing the defect of the articular surface of the humeral head from coming into engagement with the anterior glenoid margin. This effect is achieved by anchorage of the distal end of the divided subscapularis muscle to the front of the scapular neck. It is regarded as an important additional safeguard against redislocation which almost always occurs at the extremes of these movements

Operative Technique

Preparation of the Patient The operation is performed under general anaesthesia In order to ensure perfect asepsis a rigid non touch technique is advised The patient is placed supine and the affected shoulder is projected forwards by means of a small sandbag behind the scapula Careful draping of the operation area is essential It should be so effected that the whole arm is left unencumbered in order that the necessary manipulations may readily be carried out The most satisfactory method is to drape the arm and front of the shoulder in a sleeve of fine woven stockinette which should be glued to the skin over the area of the incision with sterilised

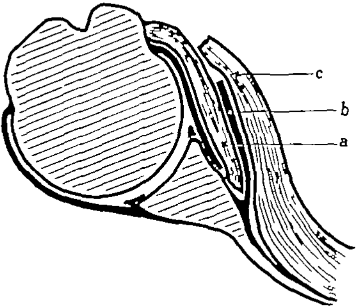

Fig 373 Putti-Platt operation Horizontal section of the left shoulder to show principles of the technique Subscapularis and capsule divided Distal portion of subscapularis ( ) sutured down in front of the neck of the scapula within the medial flap of capsule (b) Capsule (b) and proximal portion of subscapularis ( ) brought laterally to overlap the distal portion of the muscle The anterior capsular pocket is thus obliterated and the front of the joint is buttressed by mass of fibro-muscular tissue The anchorage of the distal part of the subscapularis to the scapular neck serves also to limit the range of external rotation and extension.

mastisol gum The remainder of the body is draped with sheets in the routine manner Stockinette and skin are incised together The stockinette adheres to the skin which is thus nowhere exposed

Surgical Exposure The incision is Γ-shaped (Fig 372 a) The lower (vertical) limb 4 inches in length extends distally from the coracoid process in the line of the delto-pectoral groove The upper (horizontal) limb 2 inches in length extends laterally from the coracoid process to the outer end of the clavicle The cephalic vein is retracted medially or if necessary divided and the interval between the pectoralis major and the deltoid is developed (Fig 372 b) In the upper part of the wound the medial fibres of the deltoid origin are detached from the clavicle A self retaining retractor is useful for holding the superficial muscles apart

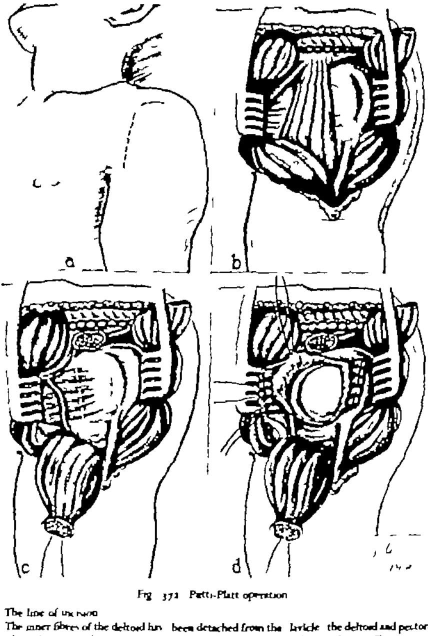

Fig 372 Putti-Platt operation

a The line of incision

b, The inner fibres of the deltoid have been detached from the clavicle the deltoid and pectoralis major have been widely separated. The conjoined coracobrachialis and biceps fibres are seen attached to the coracoid process The lateral border of pectoralis minor disappears from view deep to pectoralis major

c The coracoid process has been divided and its tip turned downwards with the attached muscles The attachment of pectoralis minor has not been disturbed. The transverse fibres of the subscapularis are seen in the depth of the wound. Note the position of the musculo-cutaneous nerve. Line of incision of subscapularis is shown.

d The subscapularis and capsule have been divided exposing the humeral head and anterior glenoid rim Note the pathological stripping of the capsule from the front of the scapular neck with formation of a deep pocket between capsule and bone

The coracoid process is cleared and divided with an osteotome half an inch from its distal end The distal fragment together with the attached coracobrachialis and

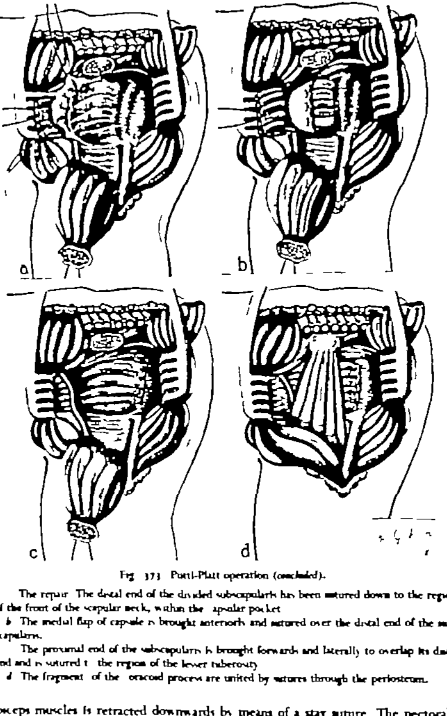

Fig 373 Putti-Platt operation (concluded).

The repair The distal end of the divided subscapularis has been sutured down to the region of the front of the scapular neck, within the capsular pocket

b The medial flap of capsule is brought anteriorly and sutured over the distal end of the subscapularis.

The proximal end of the subscapularis is brought forwards and laterally to overlap its distal end and is sutured to the region of the lesser tuberosity

d The fragments of the coracoid process are united by sutures through the periosteum.

biceps muscles is retracted downwards by means of a stay suture The pectoralis minor remains attached to the proximal part of the coracoid process and is left

undisturbed Division of the coracoid process as described is preferable to the alternative procedure of detaching the coracobrachialis and biceps origin from the bone because if this is done the coracoid process gets in the way during the subsequent exposure and renders the dissection more difficult. During the process of turning down the coracobrachialis and biceps muscles particular care must be exercised to ensure that the musculo-cutaneous nerve is protected from injury The nerve enters the deep aspect of the conjoined muscle belly (Fig 372 c) It is in a vulnerable position and may easily be damaged if it is not looked for and preserved

The subscapularis muscle is now in view (Fig 372 c) Its fibres run transversely across the depth of the wound Its upper and lower borders are defined and the muscle is divided onto a blunt director passed behind the muscle 1 inch proximal to its insertion The capsule of the shoulder joint is usually adherent to the deep aspect of the subscapularis and is often opened during the division of the muscle If not the capsule is incised by a vertical incision ¾ inch from the anterior glenoid margin

Examination of the Pathological Changes The exposure having been completed, an adequate examination of the pathological changes present within the joint is readily carried out. It is easy to confirm that the front of the capsule has been partially stripped from its attachment to the front of the neck of the scapula, leaving a potential pocket between the smooth bone and the capsule (Fig 372 d) Commonly the glenoid labrum will be seen to be separated from the underlying bone over part of its extent. Not infrequently the labrum will be found ruptured or even worn away at its anterior segment By rotating the humerus forcibly outwards and extending the shoulder to the maximum degree it will usually be possible to see or certainly to feel with a curved probe a defect of the articular surface of the humeral head

Method of Repair The repair is carried out in the following manner The exposed smooth bone of the anterior aspect of the glenoid and neck of the scapula is chipped with an osteotome or gouge in order to promote a raw vascular surface The humerus is now rotated inwards The distal (tendinous) end of the divided subscapularis muscle is anchored by four mattress sutures of strong catgut to the soft tissues which remain in the region of the front of the neck of the scapula namely the remains of the capsular attachment and the deeper fibres of origin of the subscapularis muscle (Fig 373 a) The correct insertion of these sutures represents the only difficult part of the operation A strong trocar-pointed half-circle needle of Mayo type held on a long needle-holder is ideal for the purpose and in order to facilitate the approximation of the subscapularis tendon to the scapular neck the arm must be maintained in a position of internal rotation during the insertion of the sutures and throughout the subsequent stages of the operation

The medial flap of the divided capsule is next brought forward superficial to the subscapularis tendon, to the surface of which it is sutured after scarification of the tissues to promote their union (Fig 373 b) Superficial to this again the proximal (muscular) part of the subscapularis is brought forward in such a manner that it overlaps the distal part and is sutured firmly to the aponeurosis over the region of the lesser tuberosity of the humerus (Fig 373) The repair is completed by reattachment of the divided fragment of the coracoid process and suture of the superficial planes (Fig 373 d)

Post-operative Treatment

At the conclusion of the operation the arm is bandaged across the front of the chest by means of a crepe bandage which is held securely in place by a further layer of elastic adhesive bandage The purpose of this fixation is to maintain the humerus in a position of internal rotation and thus to prevent tension on the suture lines during the period of healing The hand and wrist are left free and active wrist and finger exercises are encouraged The bandages are retained for four weeks Subsequently active elbow and shoulder exercises are commenced, with concentration at first on abduction and flexion movements External rotation exercises are not permitted until eight weeks from the time of operation

Results

Provided the steps of the operation are carried out faithfully the operation can be relied upon to give satisfactory results Out of a series of 37 cases followed up for two years or more from the time of operation the result was entirely satisfactory in 35 In 2 cases further dislocations occurred but in one of these there was a violent external rotation injury within a few weeks of the operation such as might easily have dislocated a normal shoulder

The range of shoulder movement after operation characteristically shows moderate limitation of external rotation and extension The average range of external rotation regained is 40 degrees (normal 80 degrees) and of extension in abduction 10 degrees (normal 20 degrees) All other movements are regained in full

The function of the shoulder is excellent in every respect. Strength is unimpaired pain of any significance is exceptional Most patients are able to return to heavy work and to resume normal athletic activities The limitation of external rotation and extension movements does not prove to be a material handicap and is a price willingly paid for the feeling of stability and the full confidence in the shoulder which is achieved

RECURRENT POSTERIOR DISLOCATION

Recurrent posterior dislocation of the shoulder is a rare condition Its incidence has not been accurately determined but it is probable that it represents less than 1 per cent of all cases of recurrent shoulder dislocation. The infrequency of its occurrence can be accounted for by the fact that forces tending to drive the humeral head backwards are not commonly encountered either during normal activities or from accidental violence Owing to the forward inclination of the glenoid fossa the forces resulting from falls on the outstretched arm are transmitted towards the anterior margin of the glenoid fossa rather than to its posterior aspect. Posterior dislocation can result only from a direct blow or a fall on the front of the shoulder

PATHOLOGY

Recorded cases of recurrent posterior dislocation of the shoulder are not sufficiently numerous to enable a final conclusion to be reached concerning the pathological anatomy Nevertheless, the evidence which is available indicates that the most frequent findings are first, avulsion of the capsule from the posterior glenoid margin and neck of the scapula with or without an associated detachment of the glenoid labrum and secondly a bone defect of the articular surface of the humeral

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head It is apparent therefore that the pathology is essentially similar to that of recurrent anterior dislocation

In many of the reported cases redislocations have occurred while the arm was raised in a position of forward flexion and internal rotation This can be correlated with the observation that the defect of the humeral head involves the antero-superior aspect of the articular surface and therefore comes into relation with the posterior glenoid margin during flexion and internal rotation of the humerus

OPERATIVE TREATMENT

Choice of Procedure

Operations of the suspension and sling type have proved unsuccessful A procedure which has given satisfactory results consists of reattachment of the separated portion of the capsule to the posterior aspect of the glenoid margin combined with reinforcement of the articular surface posteriorly by means of a bone block.

Surgical Exposure

The patient lies in the lateral posture with the affected shoulder uppermost An *incision 4 inches long, is made over the lower border of the spine of the scapula,* extending laterally as far as the tip of the acromion process The deltoid origin is detached from the spine of the scapula and outer aspect of the acromion The deltoid cuff is retracted downwards and outwards exposing the infraspinatus and teres minor muscles These are separated by blunt dissection and the teres minor is retracted downwards The infraspinatus is divided ½ inch from its insertion into the middle facet of the greater tuberosity of the humerus An adequate exposure *of the posterior aspect of the joint is thereby obtained (Fig 374) The capsule is* incised vertically ½ inch from the glenoid margin and the structure of the joint is carefully examined in order to determine the pathological features that may be present Particular attention is paid to the capsular attachments the glenoid labrum, and the articular contour of the humeral head One or more of these structures will show significant abnormality

Method of Repair

The repair is carried out in the following manner (Fig 375) A thin flake of bone is removed from the posterior aspect of the glenoid rim with a sharp osteotome The purpose of this is to expose a raw ascular surface of bone and thus to encourage its union with the apposing portion of the capsule which is similarly rawed by scraping with a scalpel It is not essential that the capsule be sutured to the bone because adequate apposition is maintained by the pressure of the posterior bone graft now to be applied *The incision in the capsule is repaired with sutures of fine* catgut A bed is prepared for the graft by rawing the posterior aspect of the neck of the scapula with a chisel In retracting the divided infraspinatus muscle medially for this purpose care must be taken to avoid injury to the terminal portion of the suprascapular nerve as it passes to the infraspinatous fossa through the great scapular notch The graft is obtained from the crest and outer table of the wing of the ilium (Hindenach 1947) It measures 1 inches in length by 1 inch in width The *donor site is so chosen that the surface of the graft is concave in its long axis* this facilitates accurate fitting of the graft to the concavity of the neck of the scapula

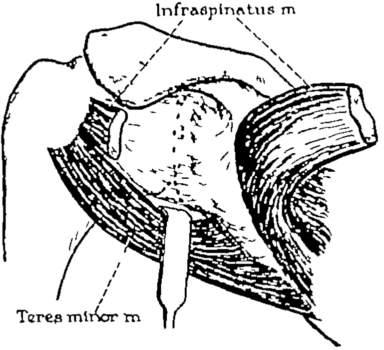

Fig 374. Approach to the posterior aspect of the shoulder (diagrammatic) After turning down the deltoid off (not shown) from the acromion process and spine of scapula the teres minor is retracted downwards and infraspinatus is divided. The capsule is seen exposed.

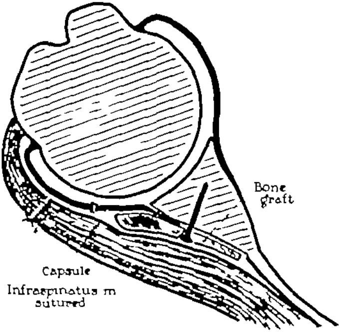

Fig 375 Operation for recurrent posterior dislocation. Horizontal section through left shoulder showing posterior bone graft applied outside the capsule The graft is covered posteriorly by the infraspinatus, shown sutured.

When the shaping of the graft has been satisfactorily completed its cancellous aspect is applied to the bed already prepared for its reception. It is so positioned that its lateral extremity projects ½ inch beyond the margin of the glenoid rim. It is fixed by one stainless steel screw driven through the graft into the neck of the scapula. The graft lies outside the joint capsule, to which it gives adequate support and which in its turn affords a satisfactory synovial lining for the articular aspect of the graft. The operation is completed by suture of the infraspinatus superficial to the graft and closure of the wound in layers.

Post-operative Care

Post-operatively the arm is bandaged across the chest for a period of six weeks. Subsequently active shoulder exercises are commenced. A satisfactory range of shoulder movement is regained within a few weeks but some residual impairment of internal rotation is to be expected.

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CHAPTER 28

Congenital Dislocation of the Hip

DENIS BROWNE

PATHOLOGY

I ASSUME THAT there are two factors in the causation of this deformity The first is a formation of the acetabulum that makes dislocation easy About this there can be hardly any doubt the liability of one sex and certain races to the condition suggests it strongly The second factor is a thrust on the knee from the uterine wall against which it lies, acting along the line of the femur to drive its head downwards and backwards (Fig 376) The hip is the only joint in the body to be found dislocated at birth It is the only one that could be dislocated by a thrust of the kind suggested and it is invariably dislocated in the only direction that such a thrust could act The existence of such a thrust is suggested by the not infrequent cases in which the shaft or neck of the femur is found to be bent at birth in exactly the way that would be expected if it instead of the joint had yielded

When the head of the femur has slipped out in the downward and backward direction suggested, and the child after birth has extended its hips it begins to move upwards owing to the action of the powerful muscles connecting the shaft of the bone to the pelvis and trunk (Fig 377) This upward movement is increased when walking begins owing to the drive of the body weight but it is limited by the extremely strong and inextensible ilio-femoral band On this band as a fulcrum the head swings backwards and forwards through a small arc as the femur flexes and extends in walking and it is probably this heavily loaded sliding movement which causes the notorious painfulness of many such dislocations in adult life This suspension of the head of the femur by a ligament would also account for the curious absence of any sign of a false joint upon the ilium in certain cases The head of the femur and the acetabulum, owing to the lack of the stimulation given by movement, fail to develop properly both before and after birth It is remarkable however how such a maldeveloped hip will catch up to a normal one in growth and become indistinguishable from it once normal position and use have been attained

An interesting point is the occurrence in certain cases after reduction of a fragmentation and flattening of the head of the femur much like that seen in Perthes disease This fragmentation is not accompanied by the pain and limitation of movement characteristic of Perthes disease and its precise significance is doubtful.

It should be noted that congenital dislocation of the hip is common in compression babies those in whom there is reason to suspect undue intra uterine pressure during pregnancy In addition to their dislocations these have the periarticular infiltration and stiffening together with the muscular atrophy produced by such pressure and also a characteristic fragility of the bones In my opinion such cases are best left untouched

Fig 376

Fig 377

Fig 376 *Sketch of an actual specimen of normal foetus in utero showing pressure of the uterine wall against the lower end of the femur and the direction in which the pressure must act.*

Fig 377 *Diagram showing how the head of the femur after being thrust out backwards from the acetabulum, as shown in Fig* 376 *moves upwards under the combined pressure of the body weight and the pull of the muscles*

DIAGNOSIS

If new born babies were to recei e as careful examination as horses do before purchase these dislocations ould be detected in the first weeks of life As it is the commonest reason for detection of the condition is slow or faulty walking In a fair number of cases I ha e had the children sent up because of congenital flat feet. As I assume such feet to be due to undue uterine pressure upon the soles this is to some degree a confirmation of the hypothesis of causation put forward The main early clinical signs of dislocation are two There is a limitation of abduction *when the hip is flexed to a right angle with the body* and the knee is higher on the affected side Neither of these signs is definite many normal hips in small babies

have very limited abduction and a difference in length between the femora is far from rare. The diagnosis turns upon the x-ray, which, though easy to interpret in the later stages, can be very puzzling in a young baby before the epiphyses become visible.

In early difficult cases the points are:

(a) The height of the head in relation to the pelvis.
(b) The distance of the shaft from the sagittal plane.
(c) The width of the ilium just above the acetabulum.
(d) The angle of the upper lip of the acetabulum.

In all these points the suspected joint must be compared either with the normal side in unilateral cases, or with an x-ray of a normal infant of the same age in bilateral ones.

In cases of doubt it is far better to put the child up in the apparatus described, which can do no harm in any event, than to waste precious time waiting for sufficient bone development to show the exact condition.

PROGNOSIS

It is difficult to be definite about this, as the whole picture appears to me to be changed by the mobile methods of treatment described in this paper. I am convinced that before I worked these out I often used to imagine a hip was properly reduced when actually the head of the femur was not properly centred in the acetabulum. It is well known that one of the factors most certain to produce osteo-arthritis is a fault in the axis or the alignment of a joint, and osteo-arthritis is of course the great danger to these patients when adult. It is also on such a fault of centring the head properly that I now tend to blame the frequent recurrence of dislocation when the child was allowed to walk free.

Given efficiency of treatment, the main factor in the prognosis is the time at which treatment is begun. If this is in the early months the child should walk, run and develop generally just like a normal infant. For the first two years the prospect of speedy and easy cure continues, and then the difficulties of reduction begin to appear and to increase until at the age of 4 the surgeon's task is a hard one. Manipulative reduction usually becomes impossible at 5 and it then becomes a question of leaving the dislocation alone, or choosing between various open operations, none of which is very satisfactory. However, a discussion of these is beyond the scope of this paper, and with increasing efficiency of diagnosis the need for them should become extremely rare in civilised countries.

TREATMENT

General Principles

1. *Keep the parts concerned in as active movement as possible during treatment.* This will have the following results:

(a) It will stimulate the growth of the defective elements of the joint as use alone can do.

(b) It will serve to work the head of the femur into the exact centre of the acetabulum by the "self-centring" action of rotation under the strong pressure of the muscles round the joint. As both redislocation after apparent reduction and

osteo-arthritis in later life are probably usually due to inexact centring of the joint this is of the utmost importance

(c) It will result in atrophy by pressure of any joint capsule or other tissue that may be interposed between the joint surfaces There is no tissue in the neighbourhood which would stand up to the violent compression it would have to undergo if interposed between the surfaces of a freely used hip joint

(d) It will develop the muscle balance which alone can keep the joint working properly

(e) It will avoid the strain on child parents, and surgeon which the usual methods of immobilisation in plaster involve

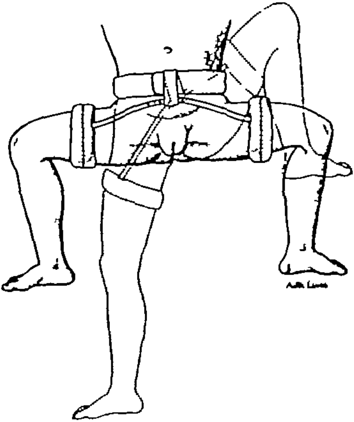


Fig 378 Child in splint recommended, showing range of movement that is permitted.

2 *Reduce the dislocation by reversing the process assumed to have caused it* In other words, get the femur into the position it was in during intra-uterine life and then try to find the track along which the head originally escaped. This should avoid damage both to the head itself and to the structures around the joint.

3 *Keep the knee back during treatment* The head of the femur can only go out backwards Owing to the ilio-femoral band it can only go backwards if the knee goes forwards *Therefore any movement can be permitted as long as the knee is kept back.* The most alarming position possible with the knee back that in which the child stands nearly upright on one leg with the other raised (Fig 378), has three safeguards

(a) The child will not put such a strain upon a joint unless it feels that it is stable It can be easily demonstrated that a strain of this sort on a dislocated or dislocating hip is most uncomfortable

(b) The position entails a violent contraction of the gluteus maximus and this extremely powerful muscle thrusts the head of the femur forwards as it pulls the great trochanter backward As dislocation is assumed to be possible only back wards the safeguard is obvious

(c) Owing to the tilting of the pelvis the extension of the hip is in fact much less than it appears

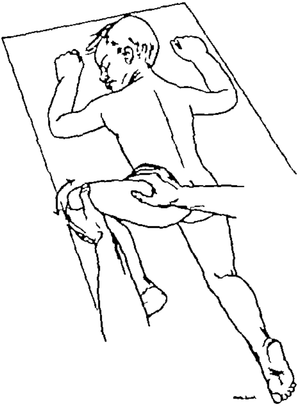


Fig 379 Manipulation for reducing the dislocation. The surgeon weight is transmitted as forcibly as may be necessary throught the right hand, while the left moves the knee up and down through the range shown to find the exact point of exit from, and consequently entry into the acetabulum

Manipulation

Under an anaesthetic the child is laid upon his face and the dislocated femur is brought up into approximately the angle in which it lay in utero The table should be so low that the surgeon can transmit his weight on to the great trochanter with a stiff arm through the heel of his hand while with the other hand he holds the knee and moves it up and down through a small arc (Fig 379) This movement of the knee is to find the exact track of entry of the head into the acetabulum

In many cases the head can be slipped in with the greatest ease and with the use of the very slightest pressure—something that never occurs with the usual methods

In other cases varying degrees of force may be needed but this is only applied to the trochanter never to the knee. The sensation given to the surgeon by reduction varies In young babies there is often no definite feeling at all merely a sinking down of the great trochanter into its normal position. In older children it aries from a clean snap to a grinding crunch as the head goes home The sign of reduction is that when the thumb is placed on the great trochanter and the knee is moved up and down, the bone cannot be felt to rise and fall under it It may be thought that the head is in place when it has merely been forced forward above the acetabulum but in this case its rise and fall on moving the knee is obvious

Fig 38 Sketch showing the lifting of the child for plastering As sistant on eithe side grasps knee and lifts, so getting the extreme of abduction by means of the body weight. This effect may be increased with advantage by pressure in the lumbar region.

In some older children it may be impossible to reduce the hip at the first attempt, but in these cases plaster is applied as described below and another attempt is made in a fortnight or so

In a bilateral case the first hip is reduced in the position illustrated, and then the femur is held by an assistant hanging over the edge of the table while the second one is dealt with I think it is a mistake to let the head out once it has been put in, and if both knees are brought up together on to the table the pelvis will be raised well above it and pressure on the trochanter will then have a strong and undesirable levering effect on the knee which should be a oided

Plastering

To allow the tissues to become adapted to their new relations it is necessary to keep the hips completely still for some four to six weeks the length of time depend-

ing on the impression of stability given to the surgeon on reduction of the dislocation Immediately the hips are in position an assistant upon either side should grasp a knee and raise the pelvis from the table far enough to allow plastering (Fig 380) It cannot possibly do good to the head to play about with the joint after reduction by snapping it in and out, and it might do considerable harm

This method of lifting and holding ensures the widest possible abduction of the thighs, and also allows the surgeon to watch the building of the back of the plaster which is, both for strength and the avoidance of sores much more important than the front The bandages should be applied so as to leave a wide free nursing area round the perineum and a strong slab should strengthen the back and its junction with the thighs (Fig 381) The knee on the dislocated side or sides should be included as this has a marked effect upon the degree of abduction

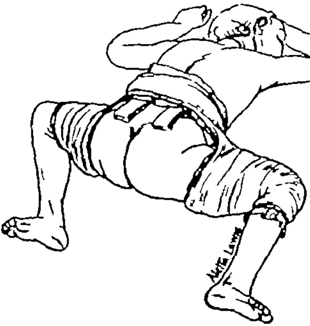


Fig 381 Plaster for dislocation of the right hip. Note the very wide nursing space and the strips of adhesive felt on either side of the spines of the lumbar vertebrae where sores are most frequent.

Mobile Treatment

When the child has been sufficiently long in the plaster it is removed and an apparatus fitted which will allow the restricted mobility that has been described as desirable This consists of a bar connecting two padded metal rings which fit round the middle of the thighs (Fig 378) The bar is suspended to a belt round the waist either in front or behind the body The anterior position is the more comfortable but the posterior keeps the more marked abduction and is consequently more suitable for difficult cases

In this splint the child is left completely free to do what he will in the way of getting about. The stages usually are first crawling then walking on all fours then a position rather like that of a Cossack dancer with the knees bent and the

buttocks close to the floor and finally an attempt to stand upright with the legs still held widely abducted by the splint

Indications for Leaving Off the Splint

I usually leave the child in the splint for nine months although I suspect that in many cases it would be safe to dispense with it much sooner In two highly instructive cases the splint was taken off against my advice after three and four months wear respectively In both the result was perfect even if I did not get the credit for it After being set free the child is again left to its own devices and usually takes about three months to get the legs into normal walking position.

In some children particularly the young and fat, localised atrophy of the subcutaneous tissues from the pressure of the splint may give a temporary appearance of a bowing of the femurs but an x ray will show that this is an illusion

Set backs

These are far less frequent than in the treatment of talipes, and consist almost entirely in the dislocation of the joint in the very early stages All that is necessary is to begin again from the beginning Such temporary slipping out seems to have no bad influence on the result

CHAPTER 29

Talipes

DENIS BROWNE

GENERAL PATHOLOGY

IN THIS ARTICLE the term talipes is taken as meaning congenital mis-shaping of the feet in which all the normal elements—bones joints muscles nerves and so on—are present If the word is used, as it occasionally is to include deformities consisting in the abnormal presence or absence of elements, or those resulting from causes acting after birth it becomes so wide in its application as to be meaningless

Mechanical Forces Acting on Foetus

I assume the cause of this mis-shaping to be mechanical forces acting on the foetus and moulding the tissues before birth as it is well known they may be moulded afterwards Familiar instances are the feet of Chinese and European ladies the rib-cages of tight lacing Victorians and the skulls and necks of certain American and African tribes It is also assumed that the tissues react to this pressure in much the same way in the foetus as in the body into which it develops I have put forward the full argument for the existence of this class of deformities elsewhere this argument mainly consisting in abstract reasoning from admitted facts

I consider these deformities to be in a quite different category from those due to intrinsic developmental errors, such as hare-lip imperforate anus, and syndactyly

This hypothesis is important as it gives a clue both to treatment and prognosis As to treatment, it may be assumed that the same persistent pressure which caused the deformity will be effective in reversing it And as to prognosis it may be assumed that certain degrees of pressure will ruin limbs beyond any hope of complete repair

The mechanical forces acting on the foetus are of three kinds which may act singly or in any combination

1 *Malposition* causing talipes equino-varus metatarsal varus, and many irregular forms

2 *Increased mechanical pressure* which in its slighter degrees, and unassociated with malposition causes the valgus and metatarsal valgus deformities that are merely exaggerations of the normal calcaneus position of a new-born baby's foot. In greater degrees this pressure causes in the foetus what it does in the adult body an atrophy of the muscles and a stiffening of the joints apparently due to interference with the venous return from the limb In mechanical pressure as opposed to hydraulic this pressure acts mainly on the lower limbs, as the upper ones are protected by the huge overhanging foetal head It may be noted that the baby with valgus talipes invariably has weak muscles the degree of weakness being proportionate to the severity of the moulding, and hence to the degree of the assumed pressure

3 *Increased hydraulic pressure* The effects of this would be the same as those of mechanical pressure in producing weakness of the muscles and stiffening of the joints but would differ in being distributed equally over all four limbs in accordance with the laws of hydraulics In the severest degrees this would produce the condition known as arthrogryposis

History of the Pregnancy in the Mother

There is no space here to go into the history of the pregnancy in the mothers of these patients a subject that has been curiously neglected. It may be noted how ever that it confirms the hypothesis put forward The gravidae with pure malposition have normal pregnancies those with mechanical pressure have small abdomens and very little amniotic fluid, and those in whom hydraulic pressure is assumed to be increased have the discomfort notoriously associated with such an increase elsewhere whether in the bladder the ear or the cerebral cavity This increased hydraulic pressure need not necessarily mean increase of the actual amount of fluid.

Associated Deformities

In addition to the mouldings which are the essence of talipes there may be other associated deformities due to developmental errors One of the commonest is spina bifida, which I have suggested may have in such cases a mechanical causative factor itself Ring constrictions congenital amputations and general smallness of the foot and leg may complicate the outlook

DIAGNOSIS

Mistakes in diagnosis by those unfamiliar with the subject are not uncommon Quite often the normal spasmodic inversion of the feet of a strong baby is mistaken for talipes and thus probably accounts for the optimism of some who claim that massage and manipulations are sufficient treatment Metatarsal varus is frequently confused with the much more severe and obstinate deformity equino-varus — almost as frequently as it and valgus talipes are overlooked during the time in early infancy when complete cure is easiest

PROGNOSIS

This depends on extrinsic and intrinsic factors Among the extrinsic ones are the time at which treatment is begun the efficiency of this treatment, and the degree of understanding and co-operation of the parents The intrinsic ones consist in the

severity of the deformity the degree of damage of tissues and the presence or absence of associated troubles

Particular care should be taken to exclude congenital dislocation of the hip which is particularly likely to co-exist (as our hypothesis might lead us to expect) with valgus talipes Shortness of the leg as a whole or of the foot itself may be blamed upon treatment if the surgeon has not detected and pointed them out when he takes over the case Finally the parents should always be warned that in a unilateral equino-varus talipes the affected calf starts smaller than the normal one and that this disproportion tends to grow greater rather than less from the natural urge to put the best foot forward.

It will be seen that accurate prognosis is far from being as easy and simple as many works on the subject would lead one to believe and calls for both experience and caution

TREATMENT

General Principles

1 *Start treatment as early as possible* preferably on the first day of life This is for several reasons

(a) The tissues of the feet are then in their most malleable state In a few weeks and with increasing rapidity as the months pass they harden up

(b) The baby is at birth almost lacking in a pain sense In my early days when tenotomy was the rule I frequently saw the tendo achillis cut without the baby taking any apparent notice The new-born child has also no memory and no imagination and will not recognise the place or the person associated with painful manipulations It is far otherwise with the child approaching a year of age to whom permanent psychological damage is unavoidable I do not consider that the simple rule of some psychologists that mental damage from trauma is in inverse proportion to age is accurate To me the sight of a child cured of talipes in babyhood dashing happily about hospital or consulting room outweighs a good deal of Viennese dogma

(c) For the first months of life the young baby s limbs during waking hours are in constant and powerful movement. This aimless kicking movement, if properly harnessed and directed will act as a series of manipulations applied to one foot by means of the other and in addition will develop the muscles and restore their impaired balance

(d) For a really good result the foot must be ready in proper position and with proper range of movement when the child needs it to stand on. This means that *correction should be* complete by the age of 8 months at the latest It should never be forgotten that if a baby is once allowed to stand on a misplaced foot a surgical disaster has occurred. The infant will have gained a wrong mental impression of the way to use a limb and as in the playing of games or the speaking of languages, a wrong start is a most obstinate handicap to overcome

2 *When possible obtain overcorrection* This term is often quite inaccurately used for the gaining of a position, different of course from the original one but which is within the normal range of movement. Its true meaning is the causing of a deformity the opposite of the *original* one with the design that the inevitable reaction of the tissues will carry the part back to normal Just as in straightening a bent stick we do not simply bring it into direct line but force it past this and let it react.

Overcorrection of a knock knee is unnecessary and would mean giving the patient bandy legs In contrast, to straighten metatarsal varus it is necessary to produce a temporary metatarsal valgus This is because of the local tendency of the foot to produce fibrous tissue in response to trauma and the universal tendency of such new-formed tissue to contract and reproduce the deformity

3 *Get a range of movement not merely a position of the foot* This obvious aim of treatment is seldom sufficiently stressed. For walking and running and for development of the muscles of the calf free movement of the ankle over a range of about a right angle is necessary This means that treatment must never fix the foot in any one position

4 *Aim for the baby s range of movement not for that of the adult* The foot of the normal new-born baby as a result of its intra-uterine position, will go up into calcaneo-valgus until the little toe touches the outer side of the leg No adult s foot will do this, but the adult range of movement is not the normal for babyhood.

5 *Never cut tendons* The temporary ease of correction gained by this is illusory as scar tissue forms in the blood poured out and this contracts to fix the original position more obstinately than before It has amazed me to see the levity with which some advise the cutting of tendons round the ankle when everyone knows the disastrous effects of such divisions round the wrist. When once a tenotomy has been done a really good result is impossible I have never seen an exception to this rule

6 *Never cut bone* The reactions of the growing tarsal bones of a child are totally different from those of a long bone One can straighten an acute bend in a tibia by means of a wedge resection with satisfactory and permanent results A similar wedge taken out of the block of tarsal bones will produce the most unexpected and unfortunate results—a curious mixture of reproduction of the original curve with shortening of the foot as a whole

7 *Manipulate the foot boldly and definitely* The fallacy of trying to pull a talipes around gradually as often advised is that under gradual pressure the foot tends to yield at the weakest spot the junction of the tarsal block and the slender and separated metatarsals This produces what is well described by the name of rocker foot, a convex under-surface to the sole

Where the age of the patient and consequent stiffness of the tissues make manual correction impossible the action of the hand should be imitated as nearly as possible by mechanical means.

8 *Use splints to maintain correction gained by manipulation not to produce the correction themselves* Only in this way can the necessary speed and accuracy of correction be gained.

9 *The pressure applied by splinting should be continuous from the first manipulation until overcorrection is gained* It is a great advantage however if in addition it can allow movement and vary slightly as it does so thus allowing and stimulating the circulation of blood and lymph and the development of the muscles

Pressure of this kind closely mimicking that assumed to have caused the condition can be applied by means of adhesive tape and adhesive felt holding the foot to an aluminium foot-piece This foot piece is so designed that, as far as possible the tissues are pulling away from it, restrained by the sticking plaster

10 *Keep the metal foundation of the splint as simple as possible* Its effects can be

varied by varying the arrangement of its parts and of the felt and sticking plaster used upon it The very simple form I now use was the survivor of many previous models nearly all of which were much more complicated and a fair number of which have since been put forward by other surgeons as improvements upon the design which superseded them

My splint consists of two L-shaped pieces of soft aluminium bent as necessary which can be connected if desired by a bar and fixed upon this at any desired angle to the sagittal plane of the body The friction joints that control this angle are simply and strongly made by passing a bolt right through both pieces of metal though for some reason instrument-makers almost invariably try to improve this by riveting a plate to the bottom of the foot piece and using this to hold the bolt

11 *Always use the splints as levers* Do not try to put the foot into position all at once but get a grip on one part of it with one end of the splint This should leave the other end of the splint projecting so that when it is in its turn strapped into position the foot is twisted in the desired way

12 *Avoid plaster-of Paris in small babies* Apart from the troubles due to its becoming soaked with urine it is kicked off if put on loosely and can produce appalling disasters if put on tightly This is because tightness produces swelling and swelling increases tightness in a vicious circle that may rapidly progress to gangrene

SPECIAL VARIETIES OF TALIPES

METATARSAL VARUS

Pathology

This common condition is due to malposition In this instead of lying with the sole against the uterine wall in the normal way the foot lies with its outer edge exposed to the moulding of this concavity (Fig 382 left) In double cases this means that the feet lie with soles pressed together in the position described as normal in Keith s *Embryology*

Metatarsal varus is a deformity that is easy to correct in early infancy but obstinate later on, as the centre of the curve is the centre of the tarsal block of bone When uncorrected it is not a really crippling deformity as the sole of the foot comes naturally flat on the ground and there is no deformity of the ankle joint. But it is ugly and difficult to shoe

When it is once corrected there is none of the inveterate tendency toward relapse that is so marked in equino-varus talipes, as no muscle tends to reproduce the deformity

Diagnosis

Metatarsal varus is frequently confused with three different conditions (a) Talipes equino-varus a far more serious and crippling condition (b) The normal inversion spasm which causes many strong babies to hold their feet twisted hard inwards just as they hold their fingers tightly clenched This is simply due to lack of co-ordination of the muscles, allowing a free-for-all in which the strongest win (c) The habit of toeing in a temporary stage which many children go through in their early years of walking There is no fixed deformity and the tendency invariably corrects itself spontaneously It does no damage to the feet and its only

disadvantages are that it looks ungraceful and causes the child to trip over its own feet and fall on its nose more than it would otherwise do

Treatment

Primary Manipulation This is simple and obvious (Fig 383)

Splinting Place a thick pad of adhesive felt built up from several layers, over the apex of the curve of the outer border of the foot. Then bind the ankle and heel to the upright limb of the splint, so that the curve of the forefoot brings it to project well inwards beyond the inner edge of the sole piece (Fig 382 right) Finally the

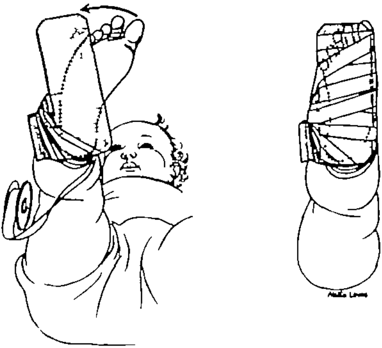


Fig 382 Showing the curve of the foot in metatarsal varus, seen from below On the left the splint has been bandaged to the leg, with a thick piece of adhesive felt placed over the apex of the convexity On the right the bandaging with sticking plaster is complete and the forefoot is bent outwards so that the original deformity is reversed into metatarsal valgus over the fulcrum of the adhesive felt.

forefoot is bent back and fastened to the sole-piece which thus acts as a lever to correct the deformity as laid down in the General Principles of Treatment

This splint may be changed fortnightly and the foot maintained in it until it remains in distinct metatarsal valgus when it is removed Usually this takes from one to three months, according to the severity of the deformity If the child is walking when treatment is begun it can continue doing so wearing a soft slipper over the splint.

Maintenance of Correction This can usually be done in the already mentioned absence of any marked tendency of the deformity to recur by teaching the mother the original manipulations as shown in Fig 383 In late cases it is safest to strap the foot into a simple night splint which holds it slightly overcorrected

VALGUS TALIPES

Pathology

Valgus talipes is a pure pressure effect It differs from the other forms of talipes in that if uncorrected it tends to produce a secondary deformity that of knock knee when the child begins to walk. As has been already mentioned, this deformity is invariably associated with weak muscles Children with weak muscles walk late and on a wide base in order to compensate for their instability This wide spreading of the feet both accentuates their valgus position and brings a strain on the knees which sends them into valgus too It is for this reason that knock knee is a disorder of weak children who walk late just as non rachitic bow legs is a disorder of strong

Fig 383 The manipulation to correct metatarsal arus, and t maintain correction when gained.

children who walk too early It is almost impossible to find a knock kneed athlete but the football fields are full of bandy legs.

In the slight degrees of this deformity the foot as a whole remains straight, being merely swung into valgus at the ankle When the pressure has been more severe the forefoot is bent outwards into metatarsal valgus It is a more difficult condition to correct than metatarsal varus and though not actually crippling, if it is not corrected in infancy a weak and ugly flat foot remains throughout life

Diagnosis

There is no condition which can readily be confused with this deformity the difficulty is to say when the calcaneus position which the new-born baby s foot holds as a relic of its intra-uterine position is so marked or so persistent that it can

severer degrees there is no equinus but a marked calcaneus element If it is desired to describe it in terms of the same character as the first two varieties of talipes I would suggest the name total varus to suggest that a varus of the ankle is added to the metatarsal varus already discussed

Pathology

Club-foot is a deformity of malposition the feet having turned inwards instead of outwards in the normal way as the limb-buds grew forward One of the many converging lines of proof of the moulding hypothesis is that in a bilateral case the deformity is never exactly equal on both sides, nor is a severe degree on one side

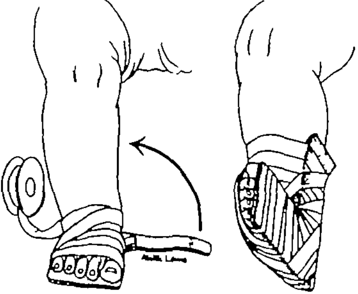


Fig 385 Fig 386

Fig 385 The first stage in splinting valgus talipes, showing the bandaging of the sole-piece of the flattened splint to the forefoot with pad of adhesive felt under the instep

Fig 386 Final stage of splinting valgus talipes, showing the ankle twisted but extreme varus, and the foot curved into metatarsal varus over the pad of adhesive felt under the instep

e er found with a mild degree on the other One foot is always just about as much worse than the other as we might expect had it been on the outer side in the necessary cross-legged position and so more exposed to the moulding force

The deformity may be one of three types

(a) The metatarsal varus of the forefoot which may be so extreme that the big toes point directly inwards when the feet are viewed from below
(b) The inward bending and moulding of the heel, so that it is both much smaller than normal and lies to the inner side of the midline of the ankle instead of its normal position on the outer side
(c) The varus position of the ankle which may be so extreme that the soles of the feet look almost directly upwards

It is often stated that there is a rotation inward of the lower end of the tibia and occasionally osteotomies are performed to remedy this I do not believe this rotation ever occurs The uterine pressure inwards on the heel behind the ankle balances the pressure inwards in front of it, and the net result is that the tibia remains straight.

Club-foot differs from all other forms of talipes in its persistent tendency to recur after apparent complete correction, and indeed after definite overcorrection I know of few happenings in surgery more surprising and disconcerting than finding a foot which one last saw in marked valgus to be strongly re-established a year or so later in the position of the original varus The first reason for this is that the stronger muscles the tibiales and those of the calf, tend to reproduce the deformity Secondly nearly all these children have an abnormal and persisting form of the common inversion spasm so that they screw their feet inwards incorrigibly when ever they can get them free Thirdly there is the influence of the bedclothes which if uncountered pull the feet all night into equino-varus Fourthly there is the general tendency of all stretched tissues to contract. All these factors act even if correction has been early and complete. When it is incomplete others join the hostile forces If the forepart points inwards the tendency of walking is to roll the foot into varus, just as it rolls into valgus if pointed outwards If the child has learned to walk with a varus foot it will for years attempt to return to this habit and most fatal of all if the heel has not been shifted to the outer side of the midline the pull of the calf muscles will twist the ankle inwards every time the foot is used

Last of all but occasionally most disconcerting, there is the interference of other members of the profession who tell the parents that the deformity is being badly overcorrected or that the child is developing a severe flat foot, and ad ise measures accordingly The experienced surgeon learns by experience to warn those responsible for the child against such well meant misdirections

When all these factors are considered, quite apart from the secondary complica tions of imperfect muscles and joints which are so often present the optimism with which an early and easy cure is often suggested may appear rather unwarranted. I do *not think that any case of genuine total varus is ever permanently cured* inside five years at the earliest. And as to what cure means I do not think a really normal looking high-arched foot is ever obtained the best result I believe possible with modern methods is a strong and supple but flat foot. With a foot of this kind however which is much like that of many ballet dancers children can run and play games extremely well Whether it would debar them from service in the army depends on how soon those responsible for the examination of recruits learn the different varieties of flat foot and realise which of them cause trouble in use and which do not

Treatment in New born Babies

Primary Manipulation In contrast to the conditions previously described, this most important part of the treatment is one of considerable difficulty It calls for careful study of the deformity strong fingers and (some would add) a hard heart However as far as this last requirement goes I am sure that drastic manipulations in early infancy reduce immeasurably the total amount of pain suffered by the patient, as compared with attempts to correct the deformity gradually

With the forefinger of one hand supporting the external malleolus the forefoot should be bent round outwards and upwards as far as it can be forced without splitting the contracted skin on the inner side Occasionally perhaps once in several hundred cases, this split occurs, and highly disconcerting and unpleasant this accident can be But it is far less serious than it looks, and if the gap is simply covered with sticking plaster and the foot then splinted as usual healing is amazingly rapid and causes very little scarring

The ideal is to get the foot around so far that the grip shown in Fig 387 can be used, and the little toe forced up until it touches the outer side of the leg Quite often this can be done at the first manipulation but in any event this position the normal intra-uterine one of the foot should be attained as soon as possible.

Fig 387 Final stage of the primary manipulation of an equino-varus talipes. It will be seen that though extreme force is being used on the sole of the foot there is no bending strain on the lower end of the tibia.

Splinting To avoid the rocker foot it is important to push the foot up into calcaneo-valgus by pressure where the apex of the rocker would come rather than to pull it up and around by the toes In consequence a pad of adhesive felt is placed under the middle of the outer side of the sole, and the foot is then bandaged to the foot piece of the splint so that its inner border is hard down upon the metal and the leg piece projects well outwards from the leg (Fig 388) When leg and leg-piece are bandaged together the ankle is thus twisted strongly into valgus, a process which it is impossible to overdo The valgus is increased gradually in successive splintings by packing up the outer side of the foot until a true overcorrection, a marked degree of valgus of the ankle and metatarsal valgus of the foot, is attained. This reversed deformity may to the inexperienced appear rather frightening, but

they may be assured that it can never be overdone I have seen hundreds of patients with club-feet suffering from unreduced varus of the ankle but never one with damage from persistent valgus

If the other foot is deformed, it is of course manipulated and splinted in the appropriate way If it is normal it is merely bandaged straight into a foot-piece to provide an anchorage in the necessary plane for the correction of the direction of the forefoot The feet are then fixed to the cross-bar in appropriate positions (Fig 389) the normal pointing slightly outwards those originally in total varus with a marked overcorrection of their original in-turning The natural reaction to the

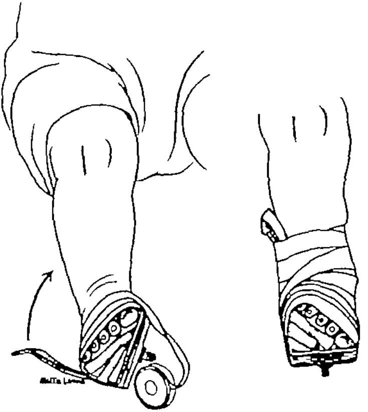


Fig 388 Feet of "double" equino-varus talipes fixed pointing outwards on the connecting bar In many cases it is advisable to turn the feet more outwards still

first violent manipulations is some oedema but this disappears in the first month or so By about the end of the fifth month in an uncomplicated case in which treatment *was begun at the proper time correction should be complete* so that without undue force the little toe can be made to touch the outer side of the leg Now comes the critical time in which the change is made from a permanent splint applied by the surgeon to a removable one applied by the mother It is at this stage that regression and failure so often begin

Application of the Calcaneus Splint It is a curious point of surgery that although fixed or spasmodic equinus of one origin or another is one of the commonest troubles of the orthopaedist there is no classical splint that will maintain the

opposite or corrected position I have succeeded after many attempts in devising a splint for this purpose which has greatly reduced the frequency of relapses at this stage and which if intelligently and persistently used ensures the maintenance of the original correction

The central and most important part of the splint is a band of soft leather gripping the ankle tightly just above the malleoli From this a shoe extends forward to hold the foot and struts run upwards to support another band just below the knee From this upper band a strap runs to a lever which can be rotated on the forepart of the sole of the shoe to vary the pull from calcaneo-valgus through a straight calcaneus

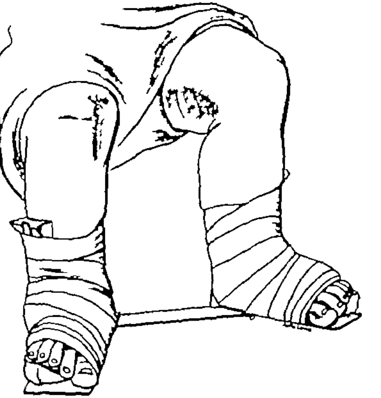


Fig 389 First stage of splinting an equino-varus talipes On the left the bandaging of the forefoot to the sole piece with the packing of adhesive felt under the outer side is shown. On the right the splinting is completed by bringing up the vertical limb of the splint t the leg so forcing the ankle into extreme algus.

pull to extreme varus The toe of the shoe is open to allow for growth and, with the same purpose the struts supporting the upper band are variable in length

Once the mother has grasped the use of this splint has become resigned to the prospect of continuing with it for five years, has been warned to ignore the advice to leave it off earlier which she is very likely to get, and has got the child broken in to it success in a difficult task is well in sight. The baby can be allowed the rolling, crawling and standing up natural to its age the splint being worn only during the long periods it spends in sleep Walking is encouraged as soon as possible and during the day the child can run about like any other

Paris but I am coming more and more to the opinion that sticking plaster and a hobble splint are both safer and more effective Manipulation and splinting are repeated at intervals of a fortnight or so until correction is attained and then the calcaneus splint is used In these difficult cases its efficiency can be considerably increased by a jointed connection which allows the feet to be turned out by means of each other at the same time as they are pulled up into calcaneo-valgus The process is tedious but the improvement that can finally be gained is both surprising and gratifying, even in cases with permanent injury from cutting operations

CHAPTER 30

Acute Infections of the Hand

F H BENTLEY

GENERAL CONSIDERATIONS

One of the most beneficent developments in modern surgery is its increasing concern with function In no condition is this trend seen to better advantage than in the hand No longer do acute infections of the hand make up the flotsam and jetsam of the Casualty Department, to be collected by the Resident for his first essays in surgery In most surgical centres these patients are treated by teams and in departments specially trained and equipped for the fine surgery the hand requires The importance of man s chief working instrument is now generally recognised

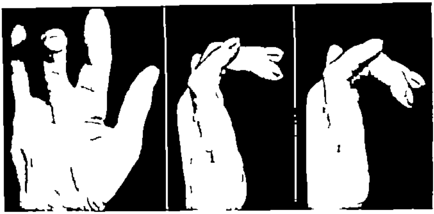
CAUSE

Acute infections of the hand usually follow minor injury involving a breach of the surface epithelium, although in a few instances such as paronychia, infection appears to develop spontaneously in patients of poor general health. The infecting organism is the *Staphylococcus pyogenes aureus* derived from the skin of the patient Rarely the causal organism is the *Streptococcus pyogenes*

PREVENTION

Nearly all trivial injuries of the hand heal readily especially if correctly treated by surgical cleanliness, rest and penicillin. Only in a minority of patients does infection develop and even in these if treatment is early and adequate the infection subsides leaving no disability The familiar sequelae of contracture and stiffness after hand infection (Fig 391) result from a missed opportunity in the prevention of infection in the first place and in its treatment later The chief significance of hand infections to the medical practitioner is that they are preventable by proper attention to the original minor injury If however infection occurs a full functional result can still be obtained if surgery is early and skilled and is combined with the use of penicillin

Prevention, early surgery and penicillin if properly combined can make the classical teachings on the more serious types of hand infection of historical interest only



b c

Fig 39 Stiff deformed hand following acute infection. The original lesion was an abrasion of the knuckles.

a, Anterior view showing loss of digit.
b Lateral view fingers fully extended.
Lateral view fingers fully flexed

TREATMENT

In the treatment of established hand infections there are four principles to follow rest penicillin, drainage of pus and restoration of movements

Fig 392 Resolution occurs more quickly if the patient is in bed for two or three days and the hand and forearm are elevated.

Rest

The hand and fingers will assume the position of rest. In the more superficial infections it is necessary only to complete the rest by supporting the hand and fore arm in a sling, and the patient may be treated as an out-patient In deeper infections

such as abscess of the *web-space or subcutaneous whitlow resolution will occur* more quickly if the patient is in bed for the first two or three days of treatment, and if the hand forearm and arm are raised on several pillows to shoulder level (Fig 392) Should there be great swelling of the hand and fingers, as when suppuration occurs deeply in the palm it is advisable also to splint the hand with the wrist held in semi-dorsiflexion and the thumb partly abducted and opposed

Penicillin

The advent of penicillin has greatly improved the prospect of a normal hand after infection and has enable surgery to become more conservative. In addition to its prophylactic use after abrasion or other injury penicillin will abort an infection which is still in the stage of cellulitis and control the spreading lymphangitis which was formerly so dangerous particularly when due to the streptococcus At a later stage after suppuration has begun penicillin will limit the spread of infection leaving only a localised condition to be dealt with surgically These are enormous benefits to the surgery of the hand

For any of these purposes penicillin is given by intramuscular injection 250 000 units at twelve hourly intervals There is sufficient laboratory and clinical evidence to show that this dosage is adequate to control staphylococcal infection in the tissues If however there are indications of a more than usually virulent infection as manifested by increasing pain toxaemia, and lymphangitis 50 000 units of penicillin should be given intramuscularly every three hours in order to maintain the concentration of penicillin in the plasma at a uniformly higher level.

Penicillin treatment is continued until the acute infective process is under control and the operation wound is healing usually a period of three to five days

Drainage of Pus

Despite the use of penicillin pus must be drained as soon as it forms a localised collection, otherwise the suppurative process will continue to spread into the surrounding tissues

Incision The incision must be placed so as to drain pus and yet not to interfere with the subsequent function of the hand In the digits therefore lateral incisions are used the midline incision is to be avoided, except when pus is pointing through necrotic tissue in this position In this circumstance the central sinus may be enlarged to facilitate drainage. Lateral incisions in a digit should not transgress the *skin creases over the interphalangeal joints If two compartments of a digit are to be* opened then separate incisions should be made in each compartment leaving a bridge of intact skin opposite the joint.

In the palm, incisions follow the skin creases. There is no place for what Bunnell has aptly described as the pernicious median incision

If there is a subcuticular collection of pus the loose cuticle should be excised *revealing usually a necrotic patch of skin over a deeper abscess (Fig 393)*

Infection of the dorsum of the hand is rare, though oedema of the dorsum is often severe in palmar infections An incision should never be made on the dorsum until it is quite certain that the suppurative process is on the dorsal and not the palmar aspect of the hand

Bloodless Field It is essential at operation to see precisely the anatomical structures

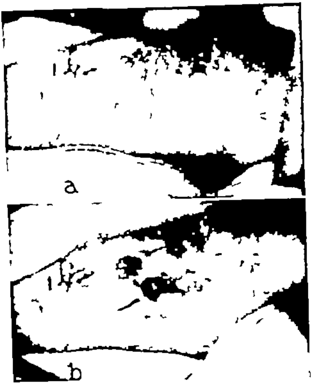


Fig 393

Cuticle raised by pus.

b Cuticle excised, revealing necrotic skin and subcutaneous abscess.

Fig 394 Bloodless field, permitting accurate surgery

and the condition of the tissues in the wound (Fig 394) For all operations therefore a pneumatic cuff is applied to the arm and maintained at a pressure of 200 mm of mercury throughout the operation. The cuff is deflated after the dressings and

bandage are applied There is no danger of tourniquet paralysis following this practice

Technique An operation for an infected hand is an exact and delicate procedure. Fine instruments are needed (Fig 395) and the tissues must be handled with respect. The margins of the incision are held open by an assistant using fine hooks or rakes the extent of the abscess cavity noted, sloughs removed and the condition of the exposed tissues (bone tendon sheath etc) carefully observed Inadequate exploration will lead to inadequate treatment and rough handling of the tissues will cause further sloughing and increased scar

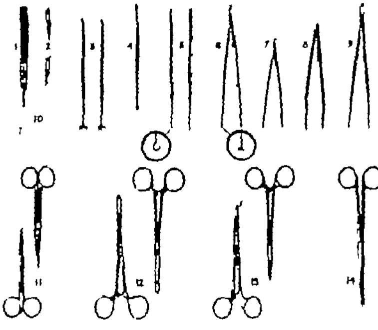


Fig 395 Instrument lay-out for operation

1 Bard Parker handle size 3 *2* Bard-Parker blades, Nos. 11 and 15 *3* Rollet lachrymal sac retractor sharp pointed *4* Stanley Boyd scoop small size *5* Kilner skin hook. (inset shows the hook approximately 1½ times natural size) *6* Waugh fine toothed tonsil dissecting 6-inch forceps (inset is approximately 1½ times natural size). *7* Fine toothed eye fixation forceps 4½ inch *8* Non toothed dissecting forceps, 5-inch *9* McIndoe non-toothed dissecting forceps, 6-inch 10 Glove rubber for drain *11* (1) Scissors, eye straight fine-pointed 4½-inch ( ) Scissors, sharp-pointed suture 5 inch *12* Allis tissue forceps, 6-inch *13* Cushing fine artery forceps, curved on flat 5½ inch *14* Suture forceps, curved on flat, 7-inch.

In order to permit of these exact conditions, the tranquillity of a general anaesthetic is obligatory even though for only a few minutes Nitrous oxide and oxygen skilfully administered may suffice though for a difficult problem it is helpful to have deeper anaesthesia such as is produced by pentothal reinforced by nitrous oxide

Drainage It is necessary to keep the lips of the incision apart for a time to allow the abscess cavity to drain For this purpose a strip of glove rubber or of wide mesh petrolatum gauze about 2 squares to the inch (tulle gras) is used as a drain for thirty-six to forty-eight hours (Fig 396) These materials have the advantage

over corrugated rubber in that they do not lead to pressure necrosis of the skin or other adjacent structures If two incisions are made in a digit two separate drains and not a through and through drain are inserted lest the bridge of skin should be compressed between the dressing and the drainage material and thereby killed

Fig 396 Three incisions with three separate drains of tulle gras

Dressings At the end of the operation the wound, drain and surrounding skin are covered by a single layer of wide mesh petrolatum gauze The finger or hand is then wrapped in several layers of dry gauze and covered with a thin layer of wool a 2 inch cotton bandage is applied sufficiently firmly to splint the part and to support the tissues without causing discomfort Firm bandaging over wool is not only neat and secures the dressing it is also comforting to a painful inflamed hand (Fig 397)

Only the affected digit is enclosed in the bandage unless the hand also is inflamed or swollen when the hand up to the wrist is similarly covered with gauze and wool, and bandaged

Fig 397 Well-bandaged thumb

Post-operative Care Rest and penicillin are continued for several days Pain is the index of progress *If the hand is comfortable and some painless movement is possible under the bandage then all is well* If spontaneous pain is complained of twelve hours or more after operation the hand should be re-examined for evidence of suppuration incompletely drained

Drains are removed after thirty-six to forty-eight hours, the wound lightly frosted with penicillin sulphathiazole powder and a flat petrolatum gauze dry dressing applied. Conditions for the dressing of the wound need to be as scrupulous as those at operation It is essential to employ an aseptic technique in a properly equipped dressing room if wound contamination is to be avoided

No further change of dressing is required for three to five days There is nothing to gain and something to lose by frequent dressings The wound is draining, any dead tissue has been removed and spread of infection is controlled the condition

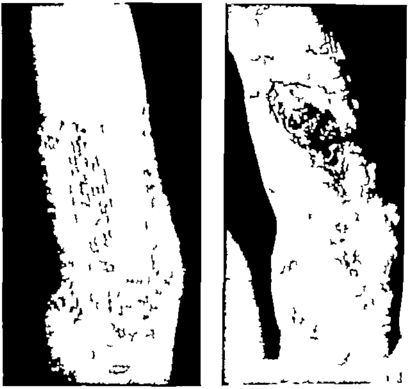


Fig 398 Fig 399

Fig 398 Mastisol-gauze dressing protecting recently healed wound

Fig 399 Granulating defect after skin necrosis (the same digit is shown pre-operatively in Fig 393)

will therefore heal There is no place for saline baths hot soaks, fomentations, or wet dressings The white sodden hands they represent belong to pre penicillin days

At the second dressing when it is observed that the inflammation has subsided and the wound is healing, the dressings can be reduced in bulk so as to facilitate movements Finger-stalls are not advisable for they tend to make the skin sodden and the patient disinclined to practise movements In the final stages when the wound requires only protection, a layer of gauze sealed with mastisol is an excellent safeguard which does not interf re with the use of the digit (Fig 398)

Skin Replacement If necrosis of skin i found at operation, a granulating defect is ine itable (Fig 399) Such an area of skin loss should not be permitted to heal from

the edges, for subsequent scar contraction will seriously limit movement. Skin loss = skin replacement is an aphorism especially true in the hand. A granulating defect therefore is to be prepared for grafting as soon as the acute inflammatory changes have subsided. Eusol compresses covered with waterproof firmly applied and changed two or three times daily will greatly assist in separation of the sloughing edges of the wound and promote formation of firm granulations. As soon as the wound is healthy a free skin graft is applied. Under adequate surgical conditions the wound will be healed and free from dressings in about ten to twelve days when exercises can begin. Treated in this way loss of skin can be compensated for and a good functional result obtained (Fig 400)

Restoration of Movements

Almost all patients regain full movements of the fingers if treatment is adequate for after penicillin and conservative surgery there is little scarring and therefore

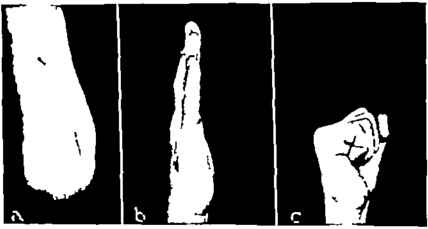


Fig 400 Defect shown in Fig 399 healed by skin grafting
The healed wound.
b c, Almost full range of movement.

little fixation to overcome. As the pain of the acute stage disappears active movements of the fingers are encouraged. When the dressings are discarded, exercises are increased with such homely helps as gripping a rubber ball or scrubbing brush. It is of obvious importance that the personality of the surgeon shall impress itself on the patient so as to produce a willingness to exercise the fingers!

Stiffness is likely when there has been extensive sloughing of skin and subcutaneous tissues, or when joints or tendons have been involved. It is also likely in cases of severe infection accompanied by marked inflammatory oedema of the neighbouring digits. The oedema is followed by peri-articular thickening around the interphalangeal joints especially in the middle-aged and elderly and although the pathological basis of these changes is obscure the crippling thickening and stiffness are both evident and difficult to cure

In such cases help can be obtained by adding the exertions of the Physiotherapy Department to those of the surgeon and patient whereby a combination of encouragement and such useful extraneous aids as massage of the digits, wax baths or

short wave diathermy lymph stasis is relieved and the circulation improved, conditions of value in restoring mobility

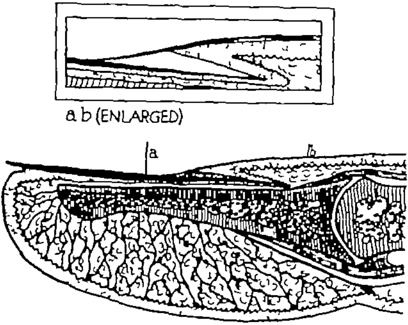


Fig 401 Longitudinal section of distal end of finger

PARONYCHIA

Anatomy

The skin fold covering the base of the nail is adherent to the nail and so forms a pocket under the skin from which pus cannot readily escape (Fig 401) The infec

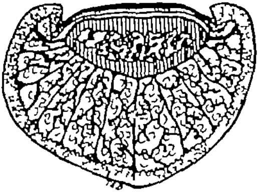


Fig 402 Transverse section across pad of finger

tion therefore tends to spread along the whole width of the fold and to burrow under the nail between it and the nail matrix, and even to perforat through the matrix into the pulp space (Fig 402)

ACUTE PARONYCHIA

Clinical Features

A zone of hyperaemia and swelling develops around the skin nail fold accompanied by a throbbing severe pain. Within one or two days suppuration occurs and pus can be seen through the skin at the base of the nail (Fig. 403). Spontaneous discharge of pus may occur but does not cure the condition because pus continues to pocket under the skin fold and often under the nail as well.

Complications

The infection may continue subacutely for many days or may spread proximally to involve the phalanx or terminal interphalangeal joint or perforate forwards into the pulp space.

Treatment

During the first few hours after bacterial invasion begins intramuscular penicillin may abort the infection. Penicillin treatment however is not conspicuously success-

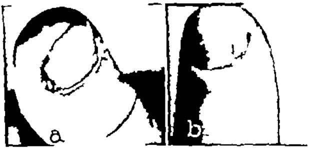


Fig. 403. a Acute paronychia early. b Acute paronychia advanced.

ful in preventing suppuration under the skin nail fold, and in the majority of cases pus forms and operation is indicated.

Operation. Operation consists in raising a rectangular flap of skin including the skin fold from the nail and nail matrix and so opening the pocket in which suppuration is occurring (Fig. 404). The flap is raised for almost 1 cm until the limit of the nail matrix is seen. Careful inspection of the base of the wound is made to observe if a small sinus leads either forwards into the pulp or proximally over the dorsum of the phalanx, in which case further incision is needed to enlarge the sinus. If there is much pus under the nail the nail should be gently avulsed from its bed and discarded. In other cases it is wise to remove the proximal third of the nail by introducing one blade of a pair of pointed scissors between the nail and matrix, cutting across the nail and removing the proximal piece. Any granulation tissue adherent to the under-surface of the skin flap or to the lateral margins of the nail matrix should be scraped away with a small sharp spoon. A piece of wide mesh petrolatum gauze is laid between the skin flap and nail matrix and the flap allowed to fall back into place. In this way immediate adhesion between skin and nail matrix is prevented and drainage is maintained. The whole operation area is then covered with a petrolatum gauze-dry dressing in the usual way.

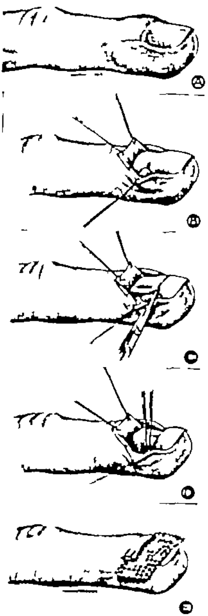


Fig 404 Stages of operation for acute paronychia

Incisions
b Skin flap raised until the limit of the nail matrix is seen
Proximal portion of nail removed to expose underlying pus.
d Demonstration of sinus leading forwards into pulp
Petrolatum gauze applied between skin flap and nail matrix

Post-operative Care The dressing is removed in four or five days when the acute infection has subsided and the base of the nail is covered with a film of granulations A petrolatum gauze-dry dressing is applied to cover the granulations and again not

disturbed for about five days At the second (or possibly third) dressing the condition usually is healed and only needs protecting with dry gauze until the new nail has grown to cover the sensitive nail bed

CHRONIC PARONYCHIA

Clinical Features

A paronychia does not always pursue the acute course just described In some patients mild inflammation around the nail fold continues for several weeks the patient complaining of slight pain and tenderness and presenting a dusky red elevation surrounding the nail base Occasionally a blob of granulation tissue is seen at the edge of the nail fold (Fig 405)

Treatment

Penicillin treatment will sometimes cure the condition although it is necessary to continue the injections of penicillin for at least seven to ten days in order to produce a lasting effect Even then, the method is not always successful and further

Fig 405 Chronic paronychia

inflammation occurs after an interval of some weeks When this happens it is necessary to operate as for an acute paronychia and, in addition to trace any granuloma to its origin and curette away all granulation tissue paying especial attention to the under-surface of the skin flap where granulations are invariably found The dressing and after-care are the same as in the acute condition and the result equally satisfactory

PULP SPACE INFECTION OR FELON

Anatomy

The pulp of the terminal compartment of a digit is made up of strong fibrous bands running between the periosteum of the phalanx and the under-surface of the skin (Figs 401 and 402) the interstices of the fibrous network are filled with fat giving the tip of the finger its characteristic combination of firmness and softness Many small blood vessels are distributed along the fibrous septa as far as the skin The terminal phalanx receives a rich blood supply from vessels reaching the bone along the joint capsule and from many periosteal branches on its anterior and posterior surfaces This free blood supply explains the unusual resistance of the terminal phalanx to infection and its power of rapid regeneration after partial necrosis

Clinical Features

A felon is the commonest of all hand infections no doubt owing to the frequency of pricks and other injuries in this part of the hand. Following a prick or apparently spontaneously a throbbing pain develops in the tip of the digit and the pulp is observed to be red swollen and tender with loss of its normal elasticity. This stage of cellulitis is followed within thirty six hours by necrosis within the pulp tissues, and as the slough liquefies an abscess forms. Accompanying these changes pain toxaemia and local tenderness increase.

If the abscess is unrelieved it leads to necrosis of the skin so that the skin of the pulp changes from bright to dusky red and then to blue-purple as necrosis threatens. Within two or three days in a severe infection the skin envelope opposite the abscess sloughs (Fig. 406) pus is discharged and the condition is eased. In untreated cases sloughing of the whole pulp is not uncommon and the presence of an undischarged slough is the usual cause of a persistent sinus or infection.

Fig. 406 Felon with skin necrosis.

Infection of the bone often follows pressure necrosis of the periosteum though it is not the whole shaft of the phalanx which is involved but only the surface of the bone opposite to the abscess cavity. If the infection continues the anterior surface of the phalanx may be destroyed but the posterior part of the bone generally survives and remains firmly adherent to the nail matrix from which it is vascularised. Sequestration of the shaft of the phalanx is uncommon. It is only in a minority of cases and usually in children or adolescents in whom the phalanx still possesses an epiphyseal cartilage that the shaft may separate from the epiphysis at the base.

Radiographs are of little help in the diagnosis of bone infection or bone death during the first three weeks of the disease. A rarefied area of bone on the radiograph or even an apparently detached tip of phalanx is of no clinical significance. If a sinus persists the pulp should be explored when a slough will be found, or rarely a loose flake of bone. Direct inspection at operation is of more value than large numbers of frequently repeated radiographs.

Complications

The pulp space is shut off from the next digital compartment by fibrous adhesion of the skin to the tendon sheath at the joint flexure Only when imperfectly treated does a felon tend to spread beyond the confines of the pulp space but should this occur the consequences may be gra e from proximal spread along the digit or from involvement of the terminal interphalangeal joint or tendon sheath

Treatment depend upon the stage at which the felon is first seen

In the Stage of Cellulitis Intramuscular injection of penicillin may abort the infection though few patients are seen sufficiently early to anticipate the formation of pus

Fig 4 7

Line of incision for pulp-space infection

b Operation for felon; wound explored

Operation for felon wound drained

After Suppuration Has Begun But Without Skin Necrosis The skin changes described above are evidence of the suppurative process within the pulp and immediate incision is needed

OPERATION An in erted J or hockey-stick incision is used (Fig 407 *a*) The line of the incision is immediately in front of the phalanx extending from the tip of the finger to a point about halfway down the terminal compartment. The pointed blade is inserted deeply into the pulp space just anterior to the bone so as to divide the septa from their attachments to the phalanx

The incision is held open with fine hooks (Fig 407 *b*) Pus is mopped out with

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Operation for felon wound drained.

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The incision is held open with fine hooks (Fig 407 *b*) Pus is mopped out with

gauze pledgets held in fine forceps loose slough picked out and the pulp cavity inspected. The forceps are passed gently to the limits of the cavity to make certain that it is fully opened up If it is not the incision is enlarged. The phalanx is carefully examined to note its condition but it should not be scraped or otherwise injured A small drain is inserted (Fig 407 c) and the routine dressing applied

Fig 4 8 Late felon with sinus.

POST-OPERATIVE CARE. The drain is removed in two days, and the wound redressed with petrolatum gauze-dry dressing It is usually healed in five to seven days, for if drainage is adequate the osteitis quickly resolves

The incision gives a good scar with no disability

After Skin Necrosis Has Occurred Pus may be visible through the cuticle and a sinus may be present (Fig 408) Once again, radiographs are of little value for the condition of the bone will be clearly evident at operation

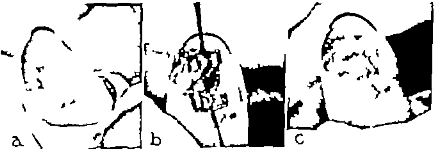

Fig 409 Felon with central skin necrosis

Area of necrotic skin
b Central defect enlarged and wound explored
Wound drained

OPERATION The hockey stick incision is used unless there is a central area of skin necrosis or a large sinus In the presence of these complications the lateral incision does not drain effectively pus continuing to discharge through the original defect The loose or raised cuticle is therefore cut away the necrotic skin exposed and the central defect enlarged (Fig 409) The skin edges are retracted, sloughs removed,

and pus mopped away The cavity is carefully exposed to ascertain its limits and to determine if further incision is needed The bone i examined Even if infected the bone has considerable powers of recovery and regeneration and only if completely free or floating should the bone be picked out For the same reason the phalanx

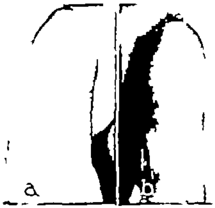

Fig 41

a, Healed scar after exploration of the pulp through central sinus
b The corresponding digit of the other hand for comparison.

is not curetted Although only a sliver of bone may remain adherent to the nail matrix an almost normal looking phalanx is likely to regenerate if it is not mutilated by surgical excision.

The wound is drained and dressed in the routine manner

POST-OPERATIVE CARE. The drain is removed in two days and a further petrolatum gauze-dry dressing applied to be changed at intervals of several days The wound may take about two weeks to heal particularly if bone is infected

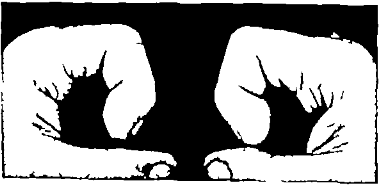

Fig 4 Full range of joint movement in the finger illustrated in Fig 4

The result will be satisfactory if exploration at operation is thorough and gentle, if the pulp tissues are not completely lost and if the bone is preserved The healed scar will be surprisingly good with adequate tactile sense in the pad and good range of joint movement (Figs 410 and 411)

When the patient comes late to operation and there is much loss of skin or pulp tissue or the phalanx is destroyed, there will be permanent deformity of the pad of the digit impairment of sensation and probably limitation of movement at the interphalangeal joint (Fig 412) Sometimes a deformed scarred pulp is painful and necessitates a partial amputation

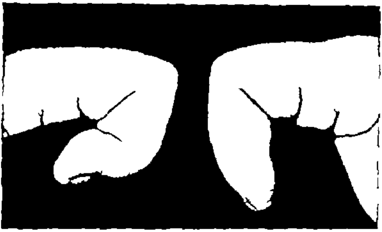

Fig 412 Deformed pad and loss of movement following extensive sloughing of the pulp

SUBCUTICULAR AND SUBCUTANEOUS INFECTIONS

A true subcuticular whitlow is an infected blister that is, the blister is the primary condition An infected blister may however cause a subcutaneous abscess infection *from the blister passing through the skin into the subcutaneous tissues* and subcuticular pus may also result from a subcutaneous abscess rupturing externally

In all instances of subcuticular pus therefore it is important to ensure either on clinical grounds or at operation that a subcutaneous abscess does not also exist

SEPTIC BLISTER

Anatomy

The dead horny layer of the skin is raised to form the roof of the blister the floor *being formed by the living cells of the epidermis (Fig 413) The serum which dis*

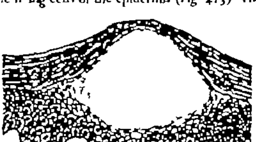

Fig 413 Section through blister

tends the blister is soon infected by organisms lying in the superficial layers of the skin

Clinical Features

A blister is caused by unusual friction against the skin Even in a horny-handed miner blistering can occur within a few days of a change from one kind of hand tool to another The most common site for blisters in the hand is over the bases of the 1st phalanges in the palm

Complications

If the blister is snipped to allow the serum to escape and an occlusive dressing is applied the condition will heal in two or three days Otherwise infection is likely the usual features of acute inflammation occur and pus is visible inside the blister The roof of the blister may rupture and spontaneous cure follow Unfortunately the horny roof often proves more resistant to the tension and infection within the blister than does the cellular base and infection passes through the skin into the subcutaneous tissues To the features of the blister therefore are added the characteristics of a subcutaneous abscess (Fig 414)

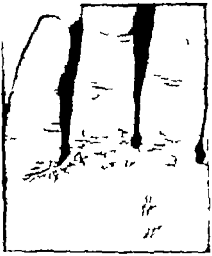

Fig 4 4. Subcutaneous abscess caused by septic blister

Treatment

The roof of the blister is snipped away and the floor of the blister examined If it is intact and in the absence of swelling of the subcutaneous tissues, only an occlusive dressing is needed for a few days

The presence of considerable swelling indicates that a subcutaneous abscess exists In such a case a minute perforation 1 to 2 mm in diameter may be seen in the floor of the blister (Fig 421) It is one of the most interesting observations in the surgery of the hand to see in a patient whose illness began with a blister the tiny round perforation of the epidermis caused by pressure necrosis and to realise how much more vulnerable to pressure and infection is thick living epithelium than thin dead cuticle

If subcutaneous pus is diagnosed on clinical grounds or by observing a perforation in the skin the operation is extended as described later under web-space infections

SUBCUTANEOUS WHITLOW OF THE DIGITS

Anatomy

The subcutaneous cellular compartments over the front of the first two phalanges of the fingers and the first phalanx of the thumb have well-defined fibrous boundaries Each compartment is occupied by areolar tissue loosely connecting the skin and tendon sheath Fibrous septa limit the space laterally and attachment of the skin to the tendon sheath at the digital flexures bounds the compartment proximally and distally The anterior digital vessels and nerves traverse the spaces and there is extensive lymphatic communication between one compartment and another and with the web spaces in the palm

Clinical Features

Subcutaneous infection of the digits is not uncommon following a prick or infected blister There is severe throbbing pain and the affected part of the finger is

Fig 415

Fig 416

Fig 415 Subcutaneous whitlow in the first digital compartment.

Fig 416 Line of incisions for subcutaneous whitlow of the first two digital compartments.

swollen and tense (Fig 415) The acute redness of the digit and the healthy state of the skin in the early stages may suggest the possibility of an infection in the tendon sheath In a subcutaneous whitlow the swelling and tenderness is most marked over one compartment there is no acute tenderness in the palm and—a most important sign—20 to 30 degrees of movement at one or other finger joint are possible without great discomfort

Complications

The infection is at first confined to one compartment but unless timely incision is made the infection spreads proximally into the next compartment or into the

adjacent web-space in the palm In an untreated case the infection may also pass to the dorsum of the finger

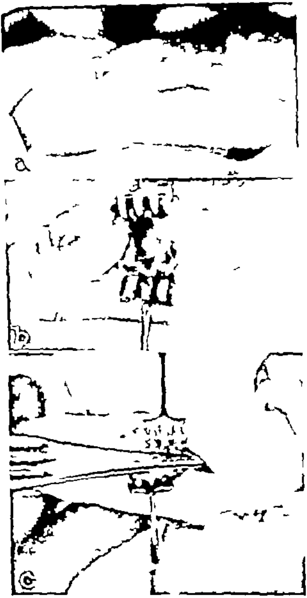

Fig 4 7 Operation for subcutaneous whitlow in the second digital compartment, with spread into the first compartment

Incision

b Abscess explored and sloughs removed

Forceps following an extension of the abscess into the first compartment.

More seriously the infection if neglected, leads to necrosis of skin over the compartment or may ulcerate through the tendon sheath or joint capsule to infect these two vital structures

Treatment

In the early stages of cellulitis penicillin treatment will abort the infection In most patients however suppuration has begun when the patient is first seen early incision is necessary to avoid the danger of necrosis of skin or of tendon sheath

Operation Unless necrotic skin is present a lateral incision is made on either side of the infected compartment just in front of the digital nerve and vessels; if two compartments are infected—as in a late case—separate incisions are made for each compartment, lea ing a bridge of intact skin opposite the interphalangeal joint flexures (Fig 416) If this bridge of skin is not preserved, subsequent contraction of the scar over the joint will limit movement

Should the skin over the compartment be necrotic lateral incisions are not advisable for the anterior sinus will continue to act as the main channel for drainage and lateral incision may lead to necrosis of the narrow strip of skin between the incision and the central defect In such a case the anterior sinus is enlarged transversely and the incision can then be extended vertically if necessary at the lateral margin of the compartment

The lips of the incision in the skin are held apart pus is mopped out and any sloughs are removed (Fig 417) Gentle search is made with fine forceps for any subcutaneous extension of the abscess cavity If the abscess extends to the other side of the compartment a counter-incision is made there or if the neighbouring compartment is involved this also is incised and drained The tendon sheath is examined It will be swollen and bulging if infected and should be incised as described below In a neglected case the tendon may be found exposed through a small necrotic hole in the sheath In the absence of clinical signs of acute tenosynovitis before operation it is wise not to open the tendon sheath further but to inject a few drops of penicillin solution (as used for the intramuscular injections) into the sheath through the defect It is likely that the tendon sheath will escape serious infection

Each skin incision is separately drained and the usual dressing applied

Post-operati e Care Drains are removed in thirty-six to forty-eight hours, and dressings repeated at intervals of several days Continued pain in the hand indicates the likelihood of extension of the infection to the next compartment or to the web-space If exploration at operation is adequate, the condition heals uneventfully in ten or twel e days

SUBCUTANEOUS INFECTION ON THE DORSUM OF THE FINGERS AND HAND

These infections are uncommon and do not differ from acute skin infections elsewhere in the body except that they may spread around the margin of the digit to involve the more complicated structures on the front of the fingers, or may infect one of the finger joints after necrosis of the extensor expansion Such infections follow injury (Fig 418) or begin as boils or carbuncles and their treatment follows the usual lines of conservative surgery occlusive dressing, and penicillin

WEB-SPACE INFECTION

Anatomy

The web-spaces between the four fingers are filled with loose areolar tissue and lie in front of the superficial palmar ligament They are thus subcutaneous, and communicate distally with the first compartment of the fingers and proximally

with the subcutaneous tissues of the palm In addition however they have deep extensions into the palm along the lumbricalis muscles to reach the fascial space behind the flexor tendons (middle palmar space) (Fig 423)

Fig 418 Subcutaneous abscess and cellulitis of dorsum of hand after cut

The web-space between the thumb and index fingers is large and differs from the other web-spaces in that the deep extension along the first lumbrical muscle leads into a fascial compartment between the thenar muscles superficially and the adductor muscle of the thumb deeply (thenar space)

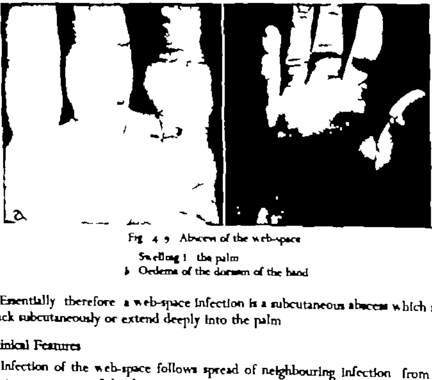

Fig 419 Abscess of the web-space

a Swelling in the palm

b Oedema of the dorsum of the hand

Essentially therefore a web-space infection is a subcutaneous abscess which may track subcutaneously or extend deeply into the palm

Clinical Features

Infection of the web-space follows spread of neighbouring infection from the first compartment of the digit or from an infected blister in the palm

better drainage of the whole cavity is obtained through a transverse incision over the abscess which can be extended towards the web-space if needed (Fig 421)

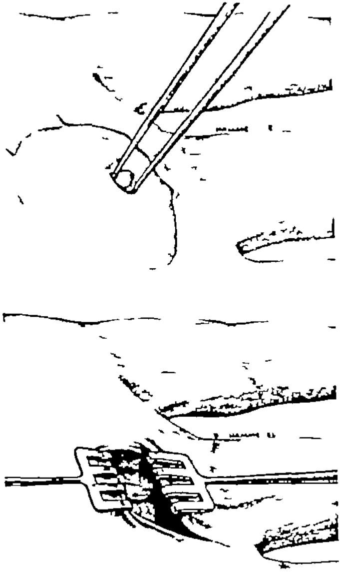

Fig 421 Exposure of web-space abscess following palmar blister

Upper Perforation of the epidermis demonstrated

Lower Transverse incision of the abscess.

The web between the thumb and index finger is explored through an incision 1 cm. in length along the line of the web (Fig 422)

The lips of the incision are held apart pus is mopped out and the extent of the cavity is carefully explored with fine forceps If a subcutaneous extension exists into

The anterior aspect of the web is red, swollen and tender and there may be much surrounding oedema particularly of the dorsum of the web-space and over the back of the hand (Fig 419)

Complications

Spread of infection in a proximal direction may occur if drainage of the abscess is delayed, either in the subcutaneous tissues or deeply into the palm When deep spread occurs the adjacent flexor tendons are in danger sloughing of the tendons in the hand illustrated in Fig 391 followed an abscess of the web-space which was not drained

Fig 42 Lines of incisions for web-space infections which follow suppuration in the digit The longer incision is also appropriate for exposure of the tendon sheath in thecal whitlow

Treatment

Incision is needed as soon as the presence of pus is diagnosed.

Operation When the abscess of the web-space follows suppuration in the finger *the web is incised vertically into the palm for a distance of 1 cm* and the incision may be extended along the margin of the first compartment of the finger if this also needs drainage (Fig 420) The palmar portion of the incision should not be longer than 1 cm or the digital nerves and vessels are in danger

Should the abscess follow a septic blister in the palm over the base of the phalanx,

better drainage of the whole cavity i obtained through a transverse incision over the abscess which can be extended towards the web-space if needed (Fig 421)

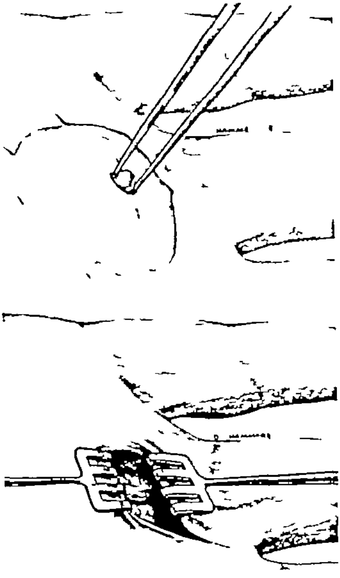

Fig 421 Exposure of web-spac abscess following a palmar blister
Upper Perforation of the epidermis demonstrated
Lower Transverse incision lot the bscess.

The web between the thumb and index finger is explored through an incision 2 cm in length along the line of the web (Fig 422)

The lips of the incision are held apart, pus is mopped out and the extent of the cavity is carefully explored with fine forceps If a subcutaneous extension exists into

the palm a second incision is needed through a convenient palmar crease near the proximal end of the pocket, otherwise pus will still collect. When, however deep extension into the palm is found a difficult problem arises for the pus lies in the fascial compartment deep to the flexor tendons (Fig 423)

Fig 422 Abscess of the first web space, showing line of incision.

In such a problem the deep pocket is explored from the web with curved sinus forceps and the track dilated. With the forceps in position a second incision 1 to

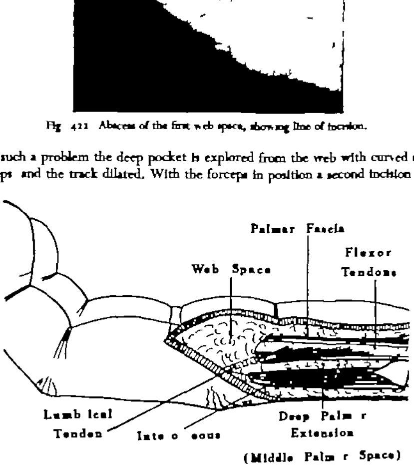

Fig 423 Longitudinal section of hand to show the extensions of web-space subcutaneously into the palm, and deeply into the palm, deep to the flexor tendons.

2 cm. long is made through the distal or middle palmar crease and the palmar fascia on to the point of the forceps In a bloodless field this can be done accurately without injury to nerves or vessels One drain is then inserted through the palmar incision and another through the wound in the web This direct approach gives better

drainage and healing and return of function are quicker than after exploration through incisions made at the margins of the hand

Post-operative Care The drains are removed after forty-eight hours In simple web-space and subcutaneous infection, the condition quickly improves and is healed at the second or third dressing If there is extension of infection into the deep fascial spaces, however discharge of pus may continue for several days The wound is dressed on alternate days and pus gently expressed from the palm In a few cases a further pocket of pus may require drainage but usually suppuration gradually lessens and the wounds are dry within two weeks It is of importance to encourage active movements of the fingers as soon as the pain disappears and to ensure that exercises are energetically pursued when the wounds are healed In order to overcome inflammatory adhesions of the flexor tendons

Fig 424. Subcutaneous abscess of the palm.

SUBCUTANEOUS INFECTION OF THE PALM

Anatomy

The skin of the palm is adherent at the skin creases to the unyielding palmar fascia Inflammatory swelling is thereby hindered and the resulting tension causes a subcutaneous palmar infection to be particularly painful

Clinical Features

Infection of the subcutaneous tissues occurs after direct injury by spread from an infected blister or from an abscess in a web-space Less commonly it may follow a haematoma due to injury The usual features of inflammation are present in the palm and pain is severe The main clinical interest in this infection lies in its differentiation from suppuration in one of the deep fascial spaces in the palm In a superficial infection there is little oedema of the dorsum of the hand and the swelling

in the palm is much more localised than in a deep palmar infection, and the skin changes are more acute (Fig 424)

Treatment

Operation An incision 2 cm long is made in a crease line close to the site of maximum tenderness and the abscess cavity explored. Pus is mopped out and the palmar fascia examined to determine whether it is intact, or whether a perforation is present, indicating the existence of a deeper abscess If the abscess is entirely subcutaneous the wound is drained in the usual way If a deep abscess is present, the palmar fascia is incised longitudinally nerves and vessels carefully avoided and drainage of the deep pocket established into the palmar wound

Post-operative Care A subcutaneous abscess heals quickly the drain is removed in thirty-six to forty-eight hours and movements are encouraged. When the wound is healed the scar should be protected for some weeks to prevent injury and re-infection.

ACUTE SUPPURATIVE TENOSYNOVITIS OR THECAL WHITLOW

This celebrated infection of the flexor-tendon sheaths is uncommon Thus among the last 2 000 patients with acute infection of the hand in the author s hospital only 3 presented intrathecal suppuration. Nevertheless, when the infection occurs it is of first importance because of the danger of damage to the tendon and of a subsequent stiff finger

Anatomy

The exquisite synovial sheaths surrounding the flexor tendons are traversed in the digital canals by synovial folds which unite sheath and tendon, and are sufficiently extensible to move with the tendons Within these synovial folds are the small blood vessels which supply the tendons If these vulnerable vessels are occluded by thrombosis or by tension within the sheath then at least part of the tendon dies prolonged suppuration, scar fixation and stiffness are certain consequences

Of less functional importance is the anatomical fact that the synovial sheaths of the tendons to the little finger and to the thumb are continuous from digit to forearm (the continuations being called the ulnar bursa and radial bursa respectively) whereas the other three synovial sheaths are interrupted in the palm (Fig 425) The danger of a thecal whitlow is not so much extension of infection to the forearm, which is extremely rare as a stiff hand from tendon damage and prolonged suppuration.

Clinical Features

Following a small puncture wound, or by spread from a more superficial whitlow the tendon sheath becomes infected in the digital canal As the sheath distends with inflammatory exudate the finger is acutely painful and inflamed. The features on which a diagnosis of intrathecal infection is made are the shape of the digit, the absence of movement, and the site of tenderness

Shape The whole digit is swollen more or less cylindrically (Fig 426) whereas when the infection is only subcutaneous the swelling is maximal in the affected compartment

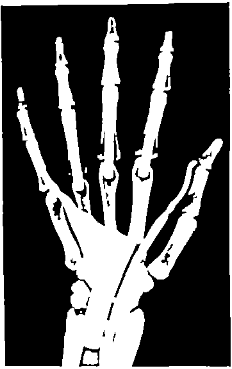

Fig 425 Outline of the synovial sheaths in the hand The sheath continuous with that of the little finger is called the *ulnar bursa* The sheath continuous with that of the thumb is called the *radial bursa*.

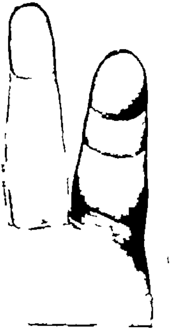

Fig 426 Drawing of thecal whitlow

Movement The slightest degree of movement causes much pain particularly any attempt at passive extension This is a most important diagnostic sign. In all other types of whitlow some painless movement is possible at one or other joint of the finger

Tenderness Acute tenderness is found in the palm 1 cm proximal to the base of the affected digit corresponding to the position of the synovial sheath in the palm

These signs are usually precise If any doubt still remains as to whether the suppuration is inside or outside the sheath operation must be performed and the answer determined

Complications

Necrosis of tendon from interference with its blood supply leads to prolonged suppuration of the infected digit with much inflammatory swelling of the rest of the hand A completely stiff digit is certain and much stiffness of other fingers to be feared

If the infection is not quickly brought under control suppuration may extend to the adjacent web spaces, and thence to one of the deep fascial compartments in the palm or the joints of the finger may become involved

Treatment

Operation Early incision is essential but instead of ruthlessly laying open the tendon sheath in its full length as was formerly practised, surgery is now able to be more gentle and conservative

A lateral incision is made in the first compartment extending into the web-space (Fig 420) the wound edges together with the neuro-vascular bundle are retracted and the tendon sheath is exposed. If infected it will bulge into the wound An incision 1 cm in length is made with a fine-pointed blade into the proximal part of the exposed sheath. Following the escape of pus 1 c c. of penicillin (5 000 to 10 000 units) is injected through the incision into the sheath to reinforce the systemic penicillin therapy the web-space is drained and dressings are applied.

When thecal infection has followed a more superficial whitlow it is advisable to expose and *incise the tendon sheath through the existing wound Unless this is* at the root of the digit it is wise also to open the sheath from the web-space or by a short incision in the palm so as to drain the proximal part of the thecal canal

Post-operative Care Persistence of throbbing pain after the first twelve to eighteen hours is an indication that drainage is unsatisfactory and the hand should be examined to determine the need for further exploration Otherwise the dressing is undisturbed until the drain is removed in forty-eight hours If the condition is satisfactory routine dressings and after-care are continued and active movements are encouraged as the pain goes Reduction of the inflammatory swelling and diminution of the discharge during the first few days are evidence that the tendon has escaped serious injury and if the patient is co-operative in his exercises, a good functional result may be expected (Fig 427) Such full return of function after thecal infection is a tribute to the virtues of conservative surgery made possible by penicillin therapy

If the condition does not quickly improve an incision into the distal part of the sheath may be necessary through the second digital compartment or a subcutaneous abscess may require drainage Constant vigilance is needed during the first few days

to ensure that a secondary spread of infection is not missed When however suppurative discharge continues for a week or more as may occur when incision has been delayed tendon infection and damage may be presumed and the wound should be re-explored to determine the condition of the exposed tendon and whether drainage is adequate If the tendon is still intact and glistening it may yet recover but if it is already sloughing the question of an early amputation of the finger should be considered for the digit is likely to be useless and continued suppuration increasing and prolonging the inflammatory oedema of neighbouring digits menaces the mobility of the surviving parts of the hand The problem calls for a nice exercise of surgical judgment for amputation is to be avoided if at all possible yet the loss of one suppurating digit may ensure the survival of a working hand

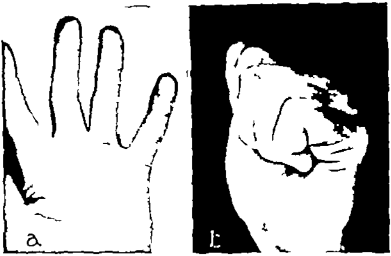

Fig 427 Result after suppurative tenosynovitis of the middle finger
Short scar in the web Full extension of fingers.
b Full flexion of fingers

SPREAD OF INFECTION INTO RADIAL OR ULNAR BURSA IN PALM In the presence of thecal infection of the thumb or little finger careful watch must be made for spread of the infection proximally along the sheath into the so-called radial or ulnar bursa in the palm (Fig 425) Suspicion of such condition is aroused by continuing pain and the diagnosis is confirmed by noting increase in swelling over whichever sheath is involved, further increase in oedema on the dorsum of the hand and—most important—marked tenderness o er the site of the bursa in the palm

This complication has not been seen in my own clinic since penicillin treatment began but should it occur the affected bursa must be opened A probe is passed from the incision in the digit along the sheath and the point is cut down on through a convenient skin crease in the palm. In a bloodless field it is possible to see and avoid nerves and vessels and make an incision 1 cm long into the sheath Penicillin solution is injected the wound drained down to the synovial sheath and routine treatment continued except that the forearm and hand should be splinted in order to gi e additional support to the inflamed parts

Treatment

Operation The joint is explored through the original wound or ulcer if this is near the joint Otherwise a postero-lateral incision is made at the margin of the extensor tendon The articular surfaces are freely exposed granulations and necrotic tissue are excised but the bone and cartilage are little disturbed except to lift out any loose sequestrum if present which is unusual If the cartilage i intact the joint may survi e but otherwise ankylosis will occur

The wound is gently packed with petrolatum gauze the finger wrapped in gauze and then immobilised in plaster-of Paris in the position of moderate flexion at all joints

Post-operative Care Systemic penicillin therapy is continued for two or three weeks when the finger is again dressed If the joint is painless and stable a small

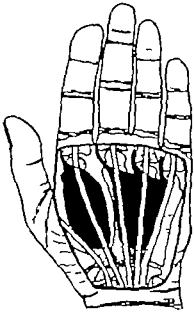

Fig 429 Outline of the fascial spaces deep in the palm. The median space is called the *middle palmar space* The lateral space is called the *thenar space*. (See also Fig 423)

occlusive dressing is applied until the narrow edge of granulations is healed. Otherwise the digit is again immobilised in plaster for two weeks

Active exercises for the fingers not in plaster are encouraged from the start. The affected joint may be permanently stiff but some movement will be possible if operation is sufficiently early cartilage is not destroyed, and exercises are energetically pursued when the plaster is removed

INFECTION OF THE FASCIAL SPACES IN THE PALM

Infections of the deep fascial spaces in the palm are like infections of the radial and ulnar bursae now extremely uncommon and will be only briefly described For a full and classical account the reader is referred to Kana el s Infections of the Hand

MIDDLE PALMAR SPACE

Clinical Features

Following suppuration in the middle ring or little finger there is exacerbation of pain and toxaemia and increased swelling over the median half of the palm This may not be readily obvious, for the hand is likely already to be very swollen especially on the dorsum Of extreme diagnostic importance is the presence of marked tenderness in the palm localised o er the space

Treatment

Operation When there is already an incision in the web-space the approach used is the one described in the section on web-space infections in which a curved sinus forcep is passed from the web into the deep fascial compartment the track dilated and a counter incision made on to the forceps through a palmar crease

If no wound exists in the web the space is opened by a transverse incision in the distal palmar crease opposite the ring finger (Fig 430) the bloodless field permitting precise access to the middle palmar space on either side of the tendons to the ring finger

Post-operative Care This was sufficiently described under web-space infection except to add that if the hand is considerably swollen the forearm and hand should be splinted with the wrist in semi-dorsiflexion and the thumb partly abducted and opposed, until the acute inflammatory stage is passed and active movements can begin

THENAR SPACE

Clinical Features

Following suppuration in the thumb index finger or web between there is exacerbation of pain and marked swelling of the thenar eminence obvious even in a swollen hand with much oedema of the dorsum Well localised extreme tenderness is found ov .r the distal part of the space

Treatment

Operation The space is readily explored through an incision 2 cm in length along the line of the web between the index finger and thumb and sinus forceps are introduced into the thenar space along the anterior surface of the thumb adductor muscle The wound is drained in routine manner

Post-operative Care An abscess in the thenar space heals quickly if there is no other suppurative lesion such as a sloughing tendon to keep the infection going The drain is removed in forty-eight hours Splinting of forearm, hand and thumb as described abo e is ad isable until the acute inflammatory stage is passed when active exercises begin

ACKNOWLEDGEMENTS

The anatomical diagrams are the work of Dr T E Barlow of the Department of Anatomy Medical School, University of Durham

The photographs were made in the Department of Photography Medical School, University of Durham; Director Mr C. J Duncan

The drawings were prepared by Mr D. P. Hammersley, Medical Artist, Department of Surgery, Medical School, University of Durham.

The instrument lay-out and points of nursing and dressing technique are the work of Sister D. M. Pratt, Royal Victoria Infirmary, Newcastle upon Tyne.

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CHAPTER 31

Nerve Suture

R B ZACHARY

During the past decade there have been a number of attempts to modify and improve the technique of apposition of the divided nerve ends in operative repair Valuable as these improvements are a far more important development has been the better understanding of the nature of nerve regeneration and the factors which influence it (Young 1942) We can now decide with more reasonable support for our opinion whether to explore an injured nerve when to do so and, if the nerve is not divided whether to resect a lesion in continuity or not. The problems to be considered in this chapter fall under two main headings (1) the indications for and the technique of exploration (2) the indications for and technique of repair

EXPLORATION

Indications

There are of course certain reasons for exploring a nerve when repair is not contemplated for example for pain or for persistent pressure on a nerve Such circumstances are outside the scope of this chapter and here we will deal only with those conditions in which exploration is desirable with a view to repair The principle which should guide the surgeon in the selection of cases is that operation is warranted when there is a strong likelihood that a nerve has suffered a complete or a serious partial division. Complete division of a nerve is responsible for more than two-thirds of the complete palsies resulting from open wounds and in such palsies there is a strong indication for exploration. In closed injuries complete paralysis seldom indicates complete section of the nerve although in a few cases division of the radial nerve has followed a closed fracture of the humerus

Incomplete paralysis in closed injuries is rarely due to partial division but in open injuries causing incomplete paralysis partial division occurs in almost one third of the cases Sometimes one can be fairly sure that the clinical picture is incompatible with a serious partial division but if one cannot be certain on this point exploration is justified for incomplete palsies in open wounds

The indications for exploration can be summarised as follows. Closed injuries complicated by paralysis seldom warrant exploration; open injuries causing complete paralysis demand operation and those resulting in incomplete paralysis need exploration if the clinical picture is compatible with a serious partial division.

Time of Exploration

The choice of time for exploration is vastly different in two main groups of cases. In the first group a complete or serious partial division of the nerve is known or suspected and for these cases early exploration is imperative. In the second group (largely composed of closed injuries) a division of the nerve in whole or in part is unlikely and exploration should be deferred until there has been sufficient time for recovery to be manifest. How long one should wait depends on the distance between the lesion and the point of innervation of the most proximal of the muscles supplied by the nerve in question. Assuming that the rate of functional recovery is at least 1 mm. per day one can calculate the time in which recovery ought to be detectable (Seddon, Medawar and Smith, 1943). If recovery is delayed much beyond the estimated time, exploration should not be postponed any longer.

In open injuries operation should be carried out as soon as possible after wound healing, for if the nerve is divided and repair is required, there is much to be lost and nothing to be gained by postponing the operation. The progressive degenerative and atrophic changes in the distal stump of the nerve, in the end organs and above all in the muscles are a heavy price to pay for delay (Bowden and Gutmann, 1944).

Primary Suture

If delay may cause such serious handicaps to recovery, should not a nerve be repaired at once if it is found to be divided at the time of the first operation on the wound? Experience has shown that, even when there has been no infection of the wound, primary nerve suture does not give uniformly good results. No recoveries after primary suture have been of higher quality than the best following secondary suture (Zachary and Holmes, 1946). There are many mediocre results and a number of complete failures.

Important hindrances to a good union in primary nerve suture are the difficulty in recognising the precise extent of the damage to the nerve on either side of the line of division, the poor condition of the nerve sheath and the difficulty in avoiding excessive tension at the suture line due to inadequate mobilisation. It is strongly recommended that at the time of the primary wound treatment the nerve ends be brought together to prevent extreme retraction, but that no formal nerve suture should be undertaken. From two to six weeks after injury is an ideal time for secondary nerve repair. The sheath is thickened sufficiently to give a good hold to the stitches, the damaged portion of the nerve is easily distinguished from normal nerve, and mobilisation can be as extensive as required for suture without tension.

TECHNIQUE

Anaesthesia

General considerations such as the condition of the patient and the availability of good general anaesthesia, are the principal factors governing the choice. The only specific advantage of local anaesthesia in nerve repair is the possibility of testing the

sensory response when stimulating the nerve immediately distal to the lesion The absence of any sensory response is an indication of interruption of the fibres but the elicitation of a response is not a sure sign that recovery is proceeding satisfactorily It may be due to the sparing of a few fibres or to the bridging of the gap by a small number of regenerating axons quite insufficient to ensure adequate re-innervation of the distal stump

If local anaesthesia is chosen it should be given by local infiltration with 0 5 per cent procaine solution subcutaneously in the line of the incision some deeper infiltration under the deep fascia in the course of the nerve is also an advantage and rarely if ever interferes with the electrical stimulation of the nerve later on The inclusion of adrenaline in the local anaesthetic in a concentration of about 1 200 000 is useful for haemostasis

Tourniquet

A pneumatic cuff is a great help when dissecting a nerve from a mass of scar tissue and it is particularly valuable for lesions in the forearm and hand Provided the tourniquet is properly applied and maintained about 50 points above the systolic pressure it can be retained for periods of two to two and one half hours without danger During this time all preparations can be completed for apposition of the nerve ends It is wise to release the tourniquet before suturing the nerve so as to prevent excessive bleeding between the apposed surfaces of the nerve with the danger of separation of the suture line or distortion of the regenerating fibres Moreover there is the possibility of disturbing the suture line in an attempt to control haemorrhage if the cuff is released after suture

The Approach

Although the incision follows in a general way the course of the nerve to be explored the choice is governed first by general surgical considerations and secondly by factors peculiar to nerve suture

The incision avoids bony prominences excising scars or giving them a wide berth It crosses all flexure lines very obliquely to prevent the development of a contracture or a prominent or unsightly scar If possible it is kept to one side of the proposed site of suture so that the skin scar is not continuous with and does not pull on the suture line during movements of the limb Sometimes it is necessary to detach muscles from their origin or insertion in order to expose the underlying nerve In these instances the incision may deviate away from the line of the nerve and pass close to the muscle attachment An example of this manoeuvre is in the exposure of the sciatic nerve in the buttock where the incision is carried laterally over the insertion of the gluteus maximus the reflexion of which gives access to this part of the nerve

The following account of the approach to the various nerve trunks is a description of the standard incisions used at one Nerve Injury Centre in Great Britain Some compromise is of course necessary if one has to deal with other lesions of nerve tendon vessel or bone in the same limb but the principles enunciated above must be adhered to

Brachial Plexus Although a horizontal incision above the clavicle will leave a good scar and allow exposure of a particular portion of the plexus it is seldom adequate

cause a contracture It also enables one to close this part of the wound without undue difficulty when the knee is flexed to 90 degrees after suture

The central portion of the nerve lies deep to the long head of biceps femoris which must be well freed on its deep surface to allow the nerve to be seen and mobilised

Posterior Tibial Nerve The incision starts at the lower end of the popliteal fossa and runs vertically downwards over the middle of the calf As the tendo achillis is approached the incision veers medially and is continued just medial to this tendon until the ankle is reached (Fig 436) The gastrocnemius muscles are separated and their aponeurosis is split The nerve can then be seen passing under the fibrous arch

Fig 436 Incisions for exploration of sciatic and posterior tibial nerves.

hich gives rise to part of the soleus The fibrous arch is di ided and the soleus is split down the centre It is unnecessary to divide the muscle completely down to its termination in the A hilles tendon The lower part of the nerve can be seen by lifting the undivided portion and can be followed downwards on the medial side of the tendon to its termination n the plantar nerves

Dissection of the Lesion

It is advisable to isolate the nerve above and below the site of injury before dissecting the damaged portion from surrounding scar With the upper and lower ends in full view one is less likely to injure the nerve than if the dissection began in

the scarred zone Moistened half-inch tape should be used for the retraction of the intact portion of the nerve and if it is to be picked up by forceps they should hold no more than the sheath.

Electrical stimulation of the nerve is best done before it is completely freed from scar Stimulators of all types have been used but a simple and effective machine is an induction coil with a make-and break, run by a small battery The apparatus should first be tested on an adjacent piece of muscle and the threshold stimulus for muscle used to commence stimulation of the nerve The apparatus can be connected to the ordinary needle electrodes of a diathermy machine using two such needle electrodes for stimulation of the nerve

If the operation is being carried out under local anaesthesia the distal trunk is tested first to assess the transmission of sensory impulses through the lesion Before stimulating the proximal trunk to ascertain the integrity of the motor fibres it is necessary to block the nerve by the injection of about 0 5 c.c of 2 per cent procaine without adrenaline about 2 or 3 cm above the lesion In order to see clearly the results of motor stimulation it is well to have the extremity prepared and towelled in such a way that the hand or foot can be exposed and covered again with the minimum of disturbance When the results of stimulation have been recorded it is wise to review all the relevant data from the history examination and exploration so that the important decision as to whether to resect or not may be made

RESECTION AND SUTURE

Indications

If the nerve is found to be divided the course to be taken is clear At times the nerve has been severed but the end bulbs remain connected by a strand of fibrous tissue The strand is nearly always central in position with symmetrical enlargement of the end bulbs This feature distinguishes the condition from a partial division of the nerve in which the bulbs on the divided portion are connected by a lateral strand of nervous tissue (Fig 437)

If the nerve is in continuity there are four main types of lesion detectable to the naked eye

1 It may be normal in appearance and to touch the lesion is one in which spontaneous recovery will occur and must be left alone

2 There may be a fusiform neuroma In general such a neuroma should not be resected but if recovery is unduly delayed or if the neuroma is very hard it is an indication of considerable disruption of fibres within the nerve sheath and resection is warranted

3 The nerve may be of normal calibre or narrower than normal, but it is *firmer* to touch and has lost the sheen of normal nerve These are the features of intraneural fibrosis usually very extensive and frequently due to traction or ischaemia If there is any evidence of conductivity the lesion should not be resected The only satisfactory way of repairing such injuries is by a nerve graft

4 If there is a lateral neuroma indicating that the nerve has been partially divided, the decision is frequently difficult. No complete set of rules can be given to cover all contingencies but the following are presented as guiding principles

(a) It is unwise to sacrifice any important function of the nerve which cannot easily be regained for example if there is a division of the median nerve at the

wrist with some preservation of sensibility on the thumb or index finger the intact portion should not be sacrificed for the quality of the sensory recovery after suture will never equal that which was retained Similarly it is unwise to sacrifice any remaining activity in the interosseous muscles of the hand in a partial division of the ulnar nerve

(b) If there is complete paralysis the damage to the continuous portion is probably more severe than it appears on the surface—particularly if the connecting strand is firmer than normal

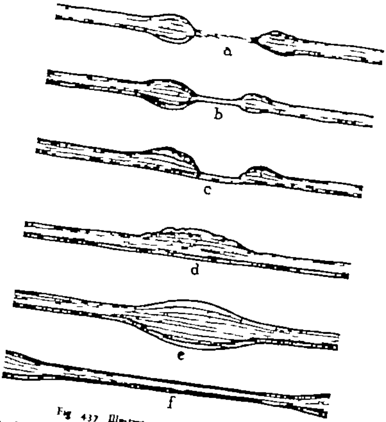

Fig 437 Illustration of operati findings.
b Complete division *d* Lateral neuroma Fusiform neuroma *f* Intraneural fibrosis

(c) If the recovery is overdue in the muscles corresponding to the part of the nerve in continuity complete resection is advisable

(d) If more than two-thirds of the nerve is divided with no evidence of conductivity in the remaining portion complete resection is usually preferable A dumb-bell shaped neuroma indicates more severe damage than a single lateral swelling (Fig 437) but t asses more accurately the extent of damage trial section is frequently necessary A transverse cut is made into the most scarred portion of the nerve and gradually deepened until normal fibres are met These can often be recognised without dividing any intact funiculi The diameter of the undamaged portion is a truer guide to the degree of damage than is the depth of the neuroma

the superficial to deep fascia medial to the nerve and in front of the epicondyle The only occasion on which it is considered advisable to place the nerve deep in the cubital fossa under the flexor mass of muscles is when the suture line would lie in front of the medial epicondyle The neuroma formed after the suture is always somewhat tender and would be less troublesome in a deep situation

The term anterior transposition can also be applied to the manoeuvre described above for exposing the median nerve in the upper forearm, for the maximum gain in length is obtained by repairing the pronator teres behind the nerve thus bringing the nerve into a more anterior plane

Anterior transposition of the radial nerve is less frequently needed Its greatest value is in division of the nerve in the musculospiral groove The upper and lower ends of the nerve are brought out of their respective wounds and one of them (depending on which is the longer) is passed across the front of the arm deep to biceps and then sutured The gain in length by this manoeuvre is often disappointing seldom more than 2 5 cm but occasionally makes suture possible in difficult circumstances

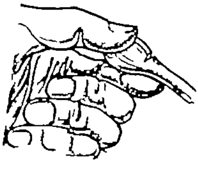

Fig 439

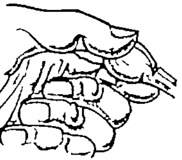

Fig 440

Fig 439 Resection of neuroma. The first cut is made at the junction of neuroma and nerve trunk

Fig 440 Resection of neuroma The nerve is turned over before the second cut is made more proximally

Resection

A razor blade is an ideal instrument but a very sharp knife blade is satisfactory With the end bulb held on the pad of the forefinger which is covered with a small piece of fine-mesh gauze a cut is made at the junction of the bulb and the nerve trunk and deepened to about two-thirds of the cross section of the nerve (Fig 439) If the face of the nerve appears satisfactory with bundles clearly pouting from the cut surface the incision is completed If not satisfactory the remaining one-third of the nerve is left intact while making another section further along the nerve trunk If an extra 2 or 3 mm is all that is needed it is often better to turn the nerve over and make the second incision on the opposite side since the portion to be cut is held more firmly in this way (Fig 440)

The extent of resection is frequently a matter of concern In general it is more important to secure good bundles in the distal stump for a satisfactory outgrowth of axons will emerge from a proximal surface which is not entirely funicular in

pattern Indeed the neuroma itself is largely composed of regenerating axons but a distal surface which is not funicular is an indication of a lot of endoneural scar which will be a serious impediment to recovery

Considerable discrepancy is sometimes found in the sizes of the proximal and the distal trunks after resection If the discrepancy is great and there is plenty of slack nerve to spare a further resection may be made so that the sizes more nearly correspond Usually it is possible to suture a large trunk to a smaller because the sheaths are mobile and adaptable to each other Oblique section of the smaller trunk is not recommended, nor I it ad Isable to inject saline into the smaller trunk to dilate it

It not infrequently happens that the nerve sheath is held very taut during resection and retracts considerably after it is cut so that the bundles stand out a long way and interfere with the apposition of the nerve sheaths This difficulty can be o ercome by incising the sheath allowing it to retract, and then dividing the bundles at a slightly higher level

Suture

For general purposes fine braided silk on an atraumatic needle is the most useful material White silk has less irritating qualities than the dyed varieties although it does not seem as strong as black silk Human hair on an atraumatic needle is ideal for the smaller nerves in which there is no tension Other materials such as stainless steel or tantalum wire are less frequently used and are less easy to manipulate by those unaccustomed to them

At this stage it is well worth while attaching some metallic markers to the sheath about 1 cm from each end of the nerve Small squares of gold foil are ideal for the purpose since they are easily identified radiographically

It is often a trying procedure to close the skin with the joint flexed after nerve repair and it is well to take advantage of the freedom of movement before suture to complete the closure as far as possible particularly the skin near the flexed joint.

Fine-pointed non-toothed, watchmaker s forceps are used to hold the rim of the di ided sheath and the first sutures to be inserted are the posterior and anterior taking a firm bite of each for they are to be used in rotating the nerve (Fig 441) The remaining gap in the sheath is closed by two to four sutures on each side depending on the size of the nerve and the congruity of the apposed ends

It is considered inad isable to wrap the sutured nerve in any foreign material such as tantalum foil It does not prevent scar tissue formation in the region of the suture line and can cause considerable damage to the nerve it surrounds Where possible the bed should be a smooth intermuscular plane away from the skin.

It is usually necessary to flex a joint (the elbow or knee) in order to suture the nerve and this position must be maintained by the assistant until the wound is closed and the limb fixed in plaster at the same angle All joints which do not require fixation for maintaining apposition of the nerve ends are left free for exercise

Post-operative Period

The limb should be elevated for forty-eight hours and active and passive movements of all free joints should be started on the day after operation Complete fixation of the flexed joint is maintained for three weeks then the plaster is changed

the sutures are removed and a turnbuckle plaster is applied, so that gradual extension of the joint can be carried out in the following two to four weeks

An x ray of the limb is taken when the plaster is changed and again when full extension of the joint has been achieved to see whether there has been any separation of the gold plates An increase in distance of 0 5 cm is permissible but any lengthening beyond this should raise the suspicion that separation has occurred at the suture line

It has been convincingly demonstrated that intensive treatment of muscles with interrupted galvanism impedes the atrophy of muscles and the proliferation of the interfascicular fibrous tissue (Jackson 1945 Gutmann and Guttmann, 1942) Treatment should be given to each paralysed muscle daily It is useless to treat a paralysed muscle once a week. Far better is it to give a few important muscles intensive galvanic stimulation than to give all muscles occasional treatment

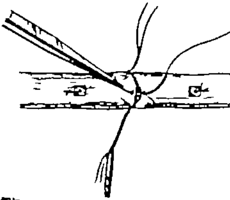

Fig 44 Nerve suture The anterior and posterior sutures are shown in place lateral sutures are being inserted The gold plates are already fixed in position. The guide sutures are not shown.

Partial Division

Some guidance has been given about the indications for complete resection and suture in partial division of the nerve In those cases in which such a procedure is not warranted there are two alternatives—loop suture and the inlay graft

Loop Suture This method involves resection and suture of the damaged segment of nerve leaving the intact portion in the form of a loop Two difficulties arise in this procedure First it is sometimes impossible to find a clear line of cleavage between the intact and the damaged portions of nerve particularly near the centre of the lesion Consequently in attempting to dissect the lesion away some damage may be done to intact fibres On the other hand if one is too cautious and leaves some scar on one side of the intact portion the purpose of this procedure is defeated for a loop cannot be made

Secondly if there is some induration of the portion in continuity it may be difficult to form a loop from it the tension on the loop may cause intraneural damage and will certainly exert a disrupting force on the suture line

The method is particularly applicable at sites close to the formation or terminal branching of nerve trunks for example the ulnar nerve above the wrist where the

motor and sensory portions are distinct for some distance within the nerve trunk (Fig 442) Other sites where this method is applicable are the median nerve just distal to its formation and the sciatic nerve above its site of terminal branching

Inlay Graft The damaged portion of the nerve is excised as for a loop suture but two features make this method applicable in cases where loop suture is unsatis factory In the first place induration of the intact portion is no impediment to repair and secondly it is not necessary to excise all the scar at the centre of the lesion where it i difficult to distinguish between scar and intact nerve A layer of scar tissue can be left on the intact portion rather than damage some intact fibres At the ends of the lesion where the section is to be made it is far easier to detect the plane of clea age and one can be fairly certain of resecting the lesion to its entire depth

After the damaged portion has been excised the gap is bridged with one or two strands of a convenient and unimportant sensory nerve (Fig 443) The grafts are

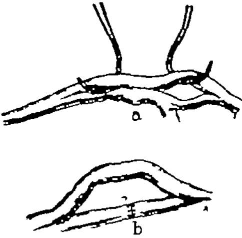

Fig 442 Loop suture

The intact upper portion of the nerve is being separated from the damaged portion.
b The loop after suture

cut about 0 5 cm. longer than the gap to allow for shrinkage which occurs They are sutured in position with human hair or fine silk or else fixed by concentrated plasma at both ends (Seddon and Medawar 1942)

If the donor nerve lies adjacent to the recipient for example the medial cutaneous nerve in relation to the median or ulnar nerve in the arm it is possible to leave it in its bed and merely free the ends sufficiently for suture (Fig 444) In this way the regional ascular connections of the graft are disturbed as little as possible

Repair of Large Gaps

Although it is possible by extreme manoeuvres and acute joint flexion to close phenomenally large gaps it has been demonstrated that the resulting excessive post operati e tension on the nerve causes further serious damage often sufficient to preclude useful recovery (Highet and Holmes 1943) It should be clearly under

stood that recoveries are exceptional after resection of great lengths of nerve and it is as well to consider alternative methods when the length of the gap after resection approaches the following critical levels ulnar 10 cm with anterior trans-

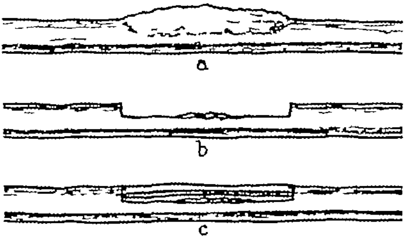

Fig 443 The inlay graft

a The lesion—a single lateral neuroma

b The gap after resection—note some scar is left on the intact portion rather than risk damaging intact fibres

A single graft sutured into position

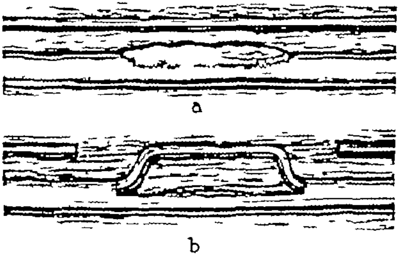

Fig 444 The inlay graft an alternative method

The lateral neuroma lies proximally the digital nerve

b The graft sutured after resection the major part of the graft remains in its original bed.

position median 8 cm radial 8 cm *with anterior transposition* lateral popliteal 9 cm medial popliteal 9 cm The methods available are bulb suture bone shortening and nerve grafting

Bulb suture is unreliable but in default of any other method it sometimes gives satisfactory results The large gap is closed by mobilising the nerve flexing the joint (knee or elbow) and sewing together the end bulbs without resection. Extension of the joint is started on the day after operation and is usually complete in three to four weeks The nerve is exposed again and the combined end bulbs resected It is then usually possible to approximate the divided ends

Bone shortening is justified if there is a malunited or ununited fracture but it is rarely warranted in other circumstances

Nerve Grafting

It has been demonstrated beyond all doubt that homografts are useless for the repair of large gaps of peripheral nerves in the human subject (Seddon and Holmes 1944 Barnes, Bacsich, Wyburn and Kerr 1946) Autogenous grafts on the other hand, have proved to be successful The chief difficulty lies in maintaining an adequate blood supply to the graft Thin grafts such as the trunks of cutaneous sensory nerves, can acquire a sufficient supply from the bed in which they lie provided that it is not densely scarred Large nerves such as the ulnar have been shown to permit satisfactory regeneration when used as grafts, but it is probable that their nutrition is relatively poor (Holmes 1947) and every effort should be made to ensure the best local conditions for their use

In addition to the inlay graft which has already been described there are three other methods

1 *Digital Nerve Grafts* For the repair of small nerves such as the digital a strand of sensory nerve (e g the sural) is inserted into the gap after resection and it is fixed by suture or the clotting of concentrated plasma

2 *Cable Grafts* Several strands of a sensory nerve are laid side by side in the gap with their ends closely apposed to the ends of the nerve trunk Fixation of the graft by suture is difficult and tedious and the plasma method is much better This technique is particularly suitable for the median nerve in the forearm

3 *Whole Thickness Grafts* This method is limited to those cases in which there is available a nerve of the same calibre as the one which is divided for example if both the median and ulnar nerves are divided with gaps so large that repair by direct suture is impossible or inadvisable the ulnar nerve can be used as a graft. If possible the graft should be taken from the proximal trunk of the nerve for such lesions are generally of long standing and advanced degenerative changes have occurred in the distal trunk of the nerve

A method has been suggested of maintaining adequate nutrition of a whole thickness nerve graft by transplanting it in two stages as a pedicle graft (Strange 1947) Applying this modification to the combined injury of median and ulnar nerves the neuromata would be resected from the proximal ends of both nerves and their freshly cut surfaces would be sutured Three weeks later the ulnar nerve would be divided more proximally allowing sufficient length to bridge the gap and the new free end of the graft would be united to the freshly sectioned distal trunk of the median nerve

The occasions on which nerve grafting is required are not frequent but the various techniques described above have a sound theoretical and practical basis and are fully justified for large gaps or for otherwise irreparable nerve lesions

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CHAPTER 32

Management of Senile and Diabetic Gangrene

A M BOYD

INTRODUCTION

Peripheral gangrene most commonly occurs in association either with senile obliterative arteritis (arteriosclerosis) or with diabetes mellitus The management of the condition under these two circumstances is described in detail The principles of the treatment of peripheral gangrene in association with senile obliterative arteritis are equally applicable to that from any arterial cause Similarly the technique for the treatment of true diabetic gangrene applies to any nonspecific infective gangrene

In both arteriosclerosis and diabetes the onset of gangrene is an acute condition demanding the immediate attention which is accorded to other acute conditions a fact not sufficiently widely recognised The precipitating factor causing the death of tissue in both cases is thrombosis of vessels to a greater or lesser extent It is essential to stop this process forthwith and to take all possible steps to repair the damage Because arteriosclerosis and diabetes are chronic diseases the onset of gangrene is apt to pass unnoticed or if noted is considered an unfortunate but inevitable sequel A no more mismanaged condition exists than that of gangrene supervening upon these chronic diseases The older the patient, the less active are the steps taken to give relief Both physicians and surgeons are to blame Many physicians fail to appreciate the urgency of the condition and the surgeon to whom the patient eventually gravitates is equally complacent Gangrene tends to be regarded as hopeless—an outlook successfully conveyed to the patient thereby increasing his misery Elderly patients with senile or diabetic gangrene are too commonly simply put to bed and left in the vain hope that some miraculous cure will take place Prolonged suffering, lack of sleep toxaemia and malnutrition lead to rapid mental and physical deterioration Last, but by no means least of the factors which increase the victims misery is the atmosphere of hopelessness which surrounds them

Wasted toxic sleepless and exhausted overwhelmed by that intense depression which only the active mind of an old person can suffer they wait for the inevitable end—long overdue amputation, frequently carried out by a young inexperienced surgeon and too often leading to unhealed sloughing stumps

In order that the method of approach and management of arteriosclerotic and diabetic gangrene should be thoroughly understood, a brief account of the pathological anatomy of the underlying arterial disease has been included

The factors precipitating gangrene in the various types of obliterative arteritis and their prognosis for life and limb are also described

A CLASSIFICATION OF OBLITERATIVE VASCULAR DISEASE

There is considerable confusion in the terminology used in connection with obliterative arterial conditions causing circulatory deficiency in the lower extremities All cases of occlusive arterial disease beginning in persons under the age of 50 are usually classified as Buerger s disease or thromboangiitis obliterans The disease in patients over the age of 50 presenting symptoms of arterial deficiency is included under the general term of arteriosclerosis Leriche (1948) in a recent analysis of over 500 personal cases confines the term thromboangiitis obliterans to patients under the age of 35 and the disease in those over 50 is considered to be of arteriosclerotic origin He admits that there is a third group in patients between 35 and 50 which shows features of both conditions which he is unable to classify

A review of the arteriographic findings and clinical features of a large number of patients suffering from deficient circulation in the lower limbs investigated between 1932 and 1949 shows that they can be classified under four main headings

1 Primary thrombosis of the popliteal artery
2 Juvenile obliterative arteritis
3 Senile obliterative arteritis
4 Primary thrombosis of the superficial femoral artery

Primary thrombosis of the popliteal artery and juvenile obliterati e arteritis are usually both included under the heading of thromboangiitis obliterans It is my belief that in the first class which comprises almost all cases in patients under 30 or 35 suffering from intermittent claudication in the calf muscles the thrombosis is traumatic and not associated with arterial disease The second class juvenile obliterative arteritis corresponds with the description given by Buerger (1908) and the condition may be a pathological entity Buerger himself included in his description of thromboangiitis obliterans patients who from their symptoms appeared to be suffering from degenerati e arterial changes The term juvenile obliterative arteritis is restricted to obliterative arteritis beginning in the feet and following a characteristic clinical course Juvenile obliterative arteritis rarely if ever begins after the age of 35

The term senile obliterative arteritis is used to cover the class of degenerative arterial changes associated with increasing age and included under the general term arteriosclerosis Arteriosclerosis is usually thought of as a disease of old age Careful examination of post-mort m and biopsy material in obliterati e arteritis from

patients under 35 reveals arteriosclerosis at an early age. Well marked calcification of the vessels has been seen in the early twenties. Arteriosclerosis is undoubtedly the most frequent cause of arterial deficiency in the lower extremities in the fourth decade. Over the age of 35 or 40 arteriosclerosis accounts for the majority of cases of occlusive vascular disease. Primary thrombosis of the superficial femoral arteries is separated from the class of senile obliterative arteritis because of the characteristic

Fig. 445. Primary popliteal thrombosis. The occluded segment extends from the upper border of the femoral condyles to the adductor opening. The last branch of the superficial femoral artery appears to limit the proximal spread of thrombosis. (From the Surgical Professorial Unit, St Bartholomew's Hospital, by courtesy of Professor Sir James Paterson Ross, K.C.V.O.)

clinical features, arteriographic findings and prognosis. In brief, almost all cases of obliterative arteritis in young people up to the age of about 35 fall into one of the first two classes, and in those over 35 into the last two classes.

The nature of the pathological changes in the blocked vessels is largely speculative and of no great importance from the point of view of treatment. The likelihood of the occurrence of *peripheral* gangrene depends on the anatomical extent and site of

the arterial occlusion rather than the cause of it. The more distal the block, the worse the outlook.

Treatment cannot be directed towards cure of the underlying condition nor can restoration of function of the blocked vessel be expected. Attention must be concentrated on the remaining healthy vessels with the object of assisting, by every possible means, the maximum development of the collateral circulation as rapidly as possible.

Fig. 446. Primary popliteal thrombosis. Arteriogram showing distal extension of thrombosis from level of femoral condyles.

The approach to the management of arterial deficiencies should be physiological rather than pathological.

PRIMARY THROMBOSIS OF THE POPLITEAL ARTERY

Pathological Anatomy

Practically all patients under the age of 35, complaining of intermittent claudication in the calf muscles, have been found to have thrombosis of the popliteal artery. Arteriographic studies in this lab show that the occlusion is confined to this artery

the remaining vessels appearing healthy The extent of the occluded segment is variable

(a) Level of knee joint to the adductor opening (Fig 445)
(b) Level of knee joint down to the termination of the artery (Fig 446)
(c) The whole length of the artery from adductor opening to the bifurcation (Fig 447)

Fig 447 Primary poplit l thrombosis. The thrombus has extended in both directions.

The fact that one end of the thrombosed segment is frequently found at the level of the knee joint strongly suggests that the causative process begins at this level Several arteriograms obtained before thrombosis has taken place show what appears to be the early lesion—a localised narrowing and irregularity of the lumen of the popliteal artery in the middle of the popliteal fossa (Fig 448) Arteriograms of patients known to have traumatic thrombosis of the popliteal artery caused by posterior dislocation of the knee joint are indistinguishable from primary thrombosis of the artery (Fig 449)

Figure 450 is a diagram illustrating the site of origin and development of primary popliteal thrombosis

Histological examination of the occluded segment obtained by arteriectomy (Boyd, 1938) from young men suffering from intermittent claudication of the calf muscles usually thought to be due to Buerger's disease shows no evidence of inflammatory changes in the arterial wall The lumen is found to be occluded by a healthy clot in various stages of organisation The wall of the artery is normal A

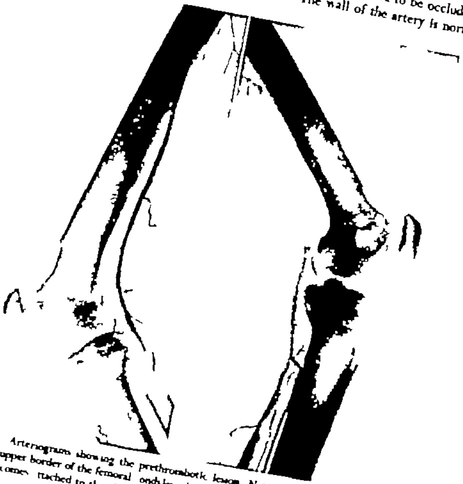

Fig 448 Arteriogram showing the prethrombotic lesion. Note site of arterial lesions at the level of the upper border of the femoral condyles where the popliteal artery enters a fibromuscular canal and becomes attached to the oblique ligament of the knee joint

number of patients with this condition have been followed up for ten years There has been no evidence of further arterial disease in striking contrast with the after histories of those patients with proven arterial disease (thromboangiitis obliterans or arteriosclerosis)

These observations in support of a traumatic origin may be outlined as follows

(a) Similarity of the arteriographic picture in traumatic thrombosis of the popliteal artery due to dislocation of the knee

(b) The absence of inflammatory or degenerative changes in the arterial wall

(c) The clinical course—more suggestive of traumatic injury than of constitutional disease

With the possibility of a traumatic origin in view a study of the anatomy of the popliteal artery was undertaken (Boyd and Wilde [Fig 451]) The popliteal artery after leaving the adductor hiatus lies in loose fatty tissue and is freely mobile Just above the level of the knee joint the artery enters a fibrous tunnel derived from the

Fig 449 Arteriogram forty-eight hours after posterior dislocation of the knee joint showing traumatic thrombosis of the popliteal artery

fascia on the deep surface of the gastrocnemii The fascial covering narrows to form a definite fibrous band $\frac{1}{4}$ to $\frac{1}{2}$ inch broad attached to the capsule of the knee joint at the level of the joint line Arteriograms show that it is at this point that thrombosis of the popliteal artery most commonly occurs It is suggested that trauma due to normal knee movements or by minor sprains or strains may cause intimal damage leading to thrombosis The possibility of traumatic thrombosis is obviously increased if there is abnormal fixation of the popliteal artery to the oblique ligament within

the fibromuscular canal from inflammatory changes possibly secondary to minor sepsis of the toes or interdigital folds

Thrombosis of the popliteal artery will give rise to intermittent claudication in the calf muscles because of the reduction in the vascular capacity preventing the increased blood flow demanded by the muscles on exercise This symptom will improve in course of time provided there are an adequate number of collateral channels able to undergo hypertrophy and dilatation The ultimate outlook for the patient is difficult to predict as his arterial reserves have been much reduced

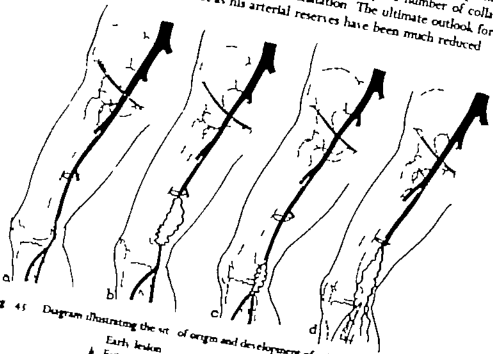

Fig 45 Diagram illustrating the site of origin and development of primary popliteal thrombosis.
Early lesion
b Extension upwards to adductor opening
Extension distally to bifurcation of popliteal artery
d Extension in both directions.

Precipitating Factors

Peripheral gangrene may be precipitated by

(a) Further trauma causing thrombosis of the collateral vessels which are circumventing the blocks
(b) Sudden extension of the thrombosis proximally or distally due to enforced recumbency on account of illness or to increase in the clotting tendency from unknown factors
(c) Reduction in blood flow due to widespread arteriosclerotic changes coming on in later life and including the collateral vessels upon which the nutrition of the limb depends

Prognosis

The prognosis therefore in primary thrombosis of the popliteal artery in young men should be guarded The immediate outlook is excellent but it must be borne

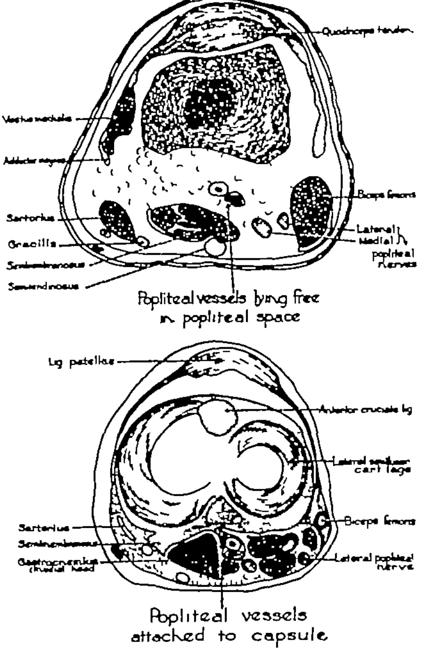

Fig 45 Tracings from transverse sections of frozen recently amputated limbs.

Above Transverse section 6 cm above knee joint showing popliteal vessels lying free in popliteal space

Below Transverse section at level of knee joint showing popliteal vessels lying in fibromuscular canal and attached to capsule (D Wilde preparations from the Anatomy Department University of Manchester)

in mind that the younger the patient the longer have his collateral vessels to maintain the blood flow A severe inroad has been made into his arterial reserves The limb has a very narrow margin of safety Further trauma the effects of a severe illness or perhaps an operation involving a prolonged period in bed and in later life the onset of degenerative arterial changes may precipitate peripheral gangrene resulting in the loss of the limb

Great care must be taken to distinguish primary thrombosis of the popliteal artery from secondary thrombosis occurring as a complication of arteriosclerosis This distinction is of fundamental importance in assessing the prognosis Senile obliterative arteritis is frequently encountered in the fourth decade On the other hand degenerative arterial changes may be delayed until much later in life Occlusion of the popliteal artery in a man of 35 may not therefore be a primary thrombosis but may be secondary to early senile obliterative arteritis with a consequently poor prognosis A similar finding in a man of 50 most commonly secondary to degenerative changes may be primary if generalised arteriosclerotic changes are absent, in which case the outlook for both life and limb is good It is therefore most important to determine whether the thrombosis is primary or secondary by careful examination of the cardiovascular system

JUVENILE OBLITERATIVE ARTERITIS

Terminology

The writer prefers the non-committal term juvenile obliterative arteritis rather than thromboangiitis obliterans (Buerger s disease) to describe the clinical syndrome due to an obliterative arteritis beginning distally in the arteries of the feet in young men

The first exhaustive and accurate study of thromboangiitis obliterans originally described by von Winiwarter in 1879 was published by Leo Buerger in 1908 and has since been known by his name

Buerger s disease like Raynaud s disease includes a number of conditions of differing pathology which with further knowledge have been separated from the general group of peripheral vascular disorders associated with obliterative arteritis of distal distribution

The term Raynaud s phenomena is now used rather than Raynaud s disease Similarly Buerger s phenomena would be more appropriate than Buerger disease for these conditions some of which are due to arteriosclerosis

After separating from this general group those cases undoubtedly due to degenerative arteritis there remains an obliterative arteritis of obscure origin possessing characteristic clinical features which until further elucidation might be called juvenile obliterative arteritis or thromboangiitis obliterans

Pathologic Anatomy

Juvenile obliterative arteritis rarely if ever begins after the age of 35 The obliterative process beginning in the small arteries of the feet gradually but relentlessly ascends the limb until the popliteal or even the femoral vessels have been occluded As a rule pain becomes intolerable demanding amputation by the

time the obliterative process has involved the popliteal artery The disease is always bilateral although more advanced in one leg than the other the more recently affected leg often coming to amputation before the limb originally affected Fungus infection of the interdigital fold is a frequent finding

Patchy phlebitis in the superficial veins of the leg is a common occurrence often preceding any signs of arterial involvement The upper extremities are rarely if ever

Fig 451 Very early juvenile obliterative arteritis, thrombosis extended to level of middle of metatarsal shaft.

affected in contrast with the distal type of senile obliterative arteritis (arteriosclerosis) in which the upper extremities are frequently involved

Arteriography shows narrowing and finally obliteration of the small arteries of the feet and plantar vessels in early cases (Fig 452) Arteriograms in more advanced cases show the relentless proximal spread of the disease the tibial arteries and eventually the popliteal arteries becoming involved (Figs 453 and 454) A line can almost be drawn across the leg at the point to which the disease has reached The

collateral vessels show the characteristic corkscrew appearance associated with rapid hypertrophy and dilatation a feature less marked in distal obliterative arteritis of arteriosclerotic origin

Clinical Features

Clinically ischaemic pain and colour changes in the toes followed rapidly by ulcerations and gangrene are usually seen Occasionally intermittent claudication

Fig 451 Juvenile obliterative arteritis—distal type—thrombosis of the plantar vessels and lower few inches of the posterior tibial artery The level to which the disease has ascended is least defined

in the small muscles of the sole of the foot, often mistaken with disastrous results for chronic foot strain, precedes the grosser ischaemic phenomena Ulceration and gangrene occur early not uncommonly in the presence of palpable pulses at the ankle

Prognosis

The course is progressive although periods of apparent quiescence in one or other leg are often seen As a rule one or both limbs are lost within three to five

years of the onset of the disease. It is my present opinion, which may have to be modified with further experience, that juvenile obliterative arteritis is confined to the lower limbs. Involvement of the upper extremities is more typical of the distal type of senile obliterative arteritis. Further experience shows that arteriosclerosis is responsible for similar obliterative arteritis beginning distally but later involving the upper limbs and eventually leading to loss of life from mesenteric, coronary or cerebral involvements.

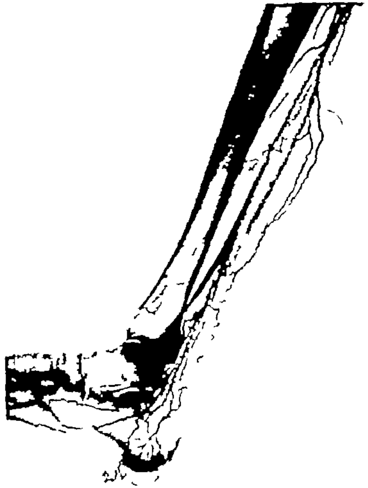

Fig. 454. Arteriogram in last case showing upward extension of thrombosis.

Macroscopic and Microscopic Changes

Patchy superficial phlebitis is rare in conditions of arteriosclerotic origin. Little help is gained from studying pathological changes in the vessels. Buerger in his original study of 19 amputated legs described the macroscopic and microscopic changes which he considered specific to this condition. The principal macroscopic change was perivascular fibrosis, welding the artery, vein and nerve into a dense cord of fibrous tissue. The vessel walls showed, on microscopy, inflammatory infiltration with fibrosis of the adventitia, some atrophy of the media, and slight

thickening of the intima from proliferation of the endothelial cells. The lumen of the vessel was blocked by clots in various stages of organisation, the thrombus eventually becoming partly recanalised. These changes are also seen in arteriosclerosis.

Any surgeon who has experience of amputating legs in senile gangrene will have noticed the difficulty of separating the various components of the neurovascular bundle which are often inextricably bound together by fibrous tissue. This change is

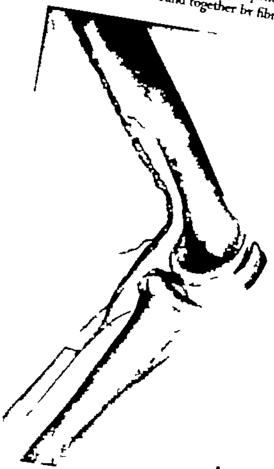

Fig 455 Arteriogram showing typical diffuse obliterating arteritis of femoral and popliteal arteries

most marked if there has been much sepsis associated with the ulceration and gangrene. In sepsis of recent origin there is gross oedema of the tissue planes around the neurovascular bundle. In late cases the inflammatory tissue has organised to dense fibrous cords which complicate any attempt at peripheral sympathectomy, isolation of the posterior tibial nerve from the artery and accompanying veins presenting the greatest difficulty. I feel that the degree of inflammatory changes depends largely on the amount of sepsis present in the perivascular lymphatics. Specimens of the posterior tibial artery obtained by arteriectomy in early cases before ulceration and sepsis had taken place do not show such marked perivascular fibrosis.

SENILE OBLITERATIVE ARTERITIS

This class includes the great majority of patients complaining of arterial deficiency of the lower limbs. There are generalised degenerative arterial changes most marked in the lower extremities. It is important to stress that diffuse obliterative arteritis is not confined to old age but is seen over a wide age period. Marked atheroma has been recorded in young children. It is by no means rare in the third

Fig 456 Calcification of the femoral artery

decade. It is the most frequent cause of occlusive arterial disease between 30 and 40 years of age and accounts for practically all organic obliterative arterial changes after age 40.

Pathologic Anatomy

Arteriography shows narrowing and irregularity of the main vessels (Fig 455). The larger branches have a beaded appearance. The pathological changes seem in some cases to fall principally on the main vessels, the smaller branches being abundant and the collateral circulation well developed. In others the changes in the

main vessels are less marked the most noticeable feature being the paucity of muscle branches which appear to end abruptly and the collateral anastomoses are conspicuous by their absence In the latter group muscular wasting is a pronounced feature There is a third small but interesting group in which the most marked clinical feature is coldness of the feet and often of the hands as well The toes and sometimes the feet also are deeply cyanotic and cold but become pink and warm when vasoconstriction is abolished by reflex heating or paravertebral block of the lumbar sympathetic chain There is little if any muscle wasting and the oscillometric readings are normal as far down as the ankle In all three groups the blood pressure is usually high In the most common group in which the main vessels are the most affected calcification of the arterial wall is commonly found (Fig 456)

b

Fig 457

Earl secondary thrombosis
b Secondary popliteal thrombosis extending upwards
Arteriogram showing secondary thrombosis of the popliteal artery beginning at le 1 of the upper border of the femoral ondyles

Factors Precipitating Gangrene

The likelihood of peripheral gangrene varies in each type and is precipitated by different factors

Group A Ma n Vessel P ncpall In ol ed—Collateral Circulation Good On the wh le gangr ne is uncommon in this group As a rule coronary thrombosis or a cerebral ac ident occurs before the failure of the peripheral circulation Occasionally however gangr ne is brought about by secondary thrombosis of the popliteal or femoral art ries (Figs 457–460) If the thrombosis is extensive the principal branches upon which the collateral circulation depends are involved resulting in severe ischaemia More ommonly the acute ischaemia accompanying thrombosis is survived but leaves the ci culation in the foot in a very precarious state gangrene

eventually being brought about by sluggish circulation in the digital vessels or precipitated by local infection burns or trauma such as injudicious chiropody

An infrequent but interesting cause of peripheral gangrene is due to blood clot or atheromatous matter separating from the walls of the main arteries (Boyd 1938) causing embolic occlusion of the digital vessel Arteriography in diffuse obliterative arteritis affecting the main vessels shows as a rule that the grossest changes are in the popliteal artery at the level of the knee joint

b

Fig 458

Arteriogram showing secondary thrombosis of the femoral artery beginning at the level of the adductor opening

b Fully developed secondary thrombosis of superficial femoral artery

The localisation of the atheromatous changes to the popliteal artery are probably determined by minor trauma brought about by movements of the knee joint (cf Primary Thrombosis of Popliteal Artery) If Duguid s (1946) views are correct, that the intimal changes are secondary to the deposit of mural clot, the marked atheromatous changes so commonly seen in the popliteal artery are probably caused by fibrinous deposits on the damaged intima

More rarely the grossest changes are seen in the superficial femoral artery particularly in the neighbourhood of the adductor hiatus another point at which the artery becomes relatively fixed and therefore liable to the affect of trauma

main vessels are less marked the most noticeable feature being the paucity of muscle branches which appear to end abruptly and the collateral anastomoses are conspicuous by their absence In the latter group muscular wasting is a pronounced feature There is a third small but interesting group in which the most marked clinical feature is coldness of the feet and often of the hands as well The toes and sometimes the feet also are deeply cyanotic and cold but become pink and warm when vasoconstriction is abolished by reflex heating or paravertebral block of the lumbar sympathetic chain There is little if any muscle wasting and the oscillometric readings are normal as far down as the ankle In all three groups the blood pressure is usually high In the most common group in which the main vessels are the most affected calcification of the arterial wall is commonly found (Fig 456)

Fig 457

a Early secondary thrombosis
b Secondary popliteal thrombosis extending upwards.
c Arteriogram showing secondary thrombosis of the popliteal artery beginning at level of the upper border of the femoral condyles

Factors Precipitating Gangrene

The likelihood of peripheral gangrene varies in each type and is precipitated by different factors

Group A Main Vessel Principally Involved—Collateral Circulation Good On the whole gangrene is uncommon in this group As a rule coronary thrombosis or a cerebral accident occurs before the failure of the peripheral circulation Occasionally however gangrene is brought about by secondary thrombosis of the popliteal or femoral arteries (Figs 457–460) If the thrombosis is extensive the principal branches upon which the collateral circulation depends are involved resulting in severe ischaemia More commonly the acute ischaemia accompanying thrombosis is survived but leaves the circulation in the foot in a very precarious state gangrene

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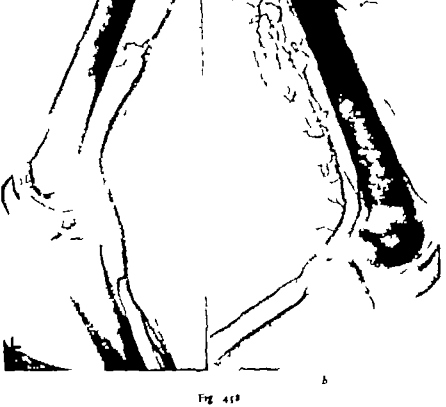

b

Fig 458

Arteriogram showing secondary thrombosis of the femoral artery beginning t the lev l of the adductor opening

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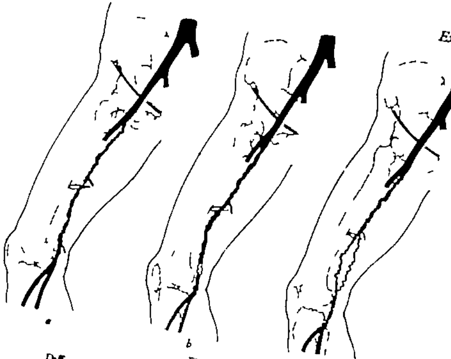


Fig 459

Diffuse obliterati arteritis
b Secondary thrombosis beginning at the level of the upper border of the condyle
Fully developed secondary thrombosis of popliteal artery

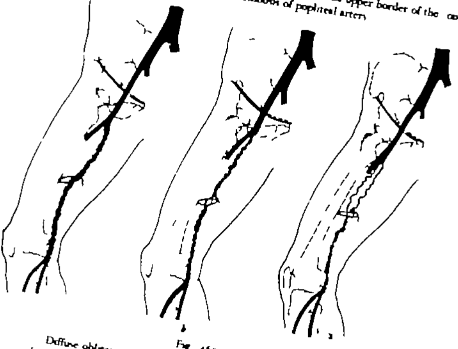


Fig 460

Diffuse obliteratis rteritis
b Secondary thrombosis beginning at the level of the adductor opening
Fully developed secondary thrombosis of superficial femoral rtery

In either case the clinical features are characteristic There are repeated attacks of gangrene involving one toe after another The writer has amputated three toes in nine months in a patient with this condition (Boyd 1938) Showers of emboli however may be the cause of gangrene limited to the tips of several toes a common occurrence in peripheral gangrene associated with senile obliterative arteritis

Group B Collateral Vessels and Muscle Vessels Most Involved In this group secondary thrombosis of the main arteries most commonly the popliteal but occasionally both popliteal and superficial femoral is the most frequent precipitating factor in the production of peripheral gangrene

Group C Distal Type Peripheral gangrene is not very common in this group It is remarkable how cold and blue toes can remain year after year without necrosis occurring Gangrene is most commonly precipitated by

(a) *Sepsis*—paronychia or sepsis gaining entry from cracks in the interdigital folds caused by fungus infections.
(b) *Injury*—from ill-fitting shoes unwise chiropody and hot water bottle burns

Gangrene may involve the whole toe or more commonly may occur in attacks in which small patches of gangrene appear at the tips of several toes, separate and heal slowly or remain as indolent ulcers.

Prognosis for the Three Groups

Diffuse obliterative arteritis is by far the most common type of arterial disease found in patients suffering from peripheral gangrene in the latter *half of life* The likelihood of gangrene however differs markedly in the three groups

Group A Where the main vessels are principally involved death from coronary or a cerebral catastrophe is more likely to occur than peripheral gangrene This point is important because the patient or his relatives will ask whether loss of the limb is likely to occur The surgeon can with reasonable confidence announce that peripheral gangrene is unlikely mentioning if he considers wise the danger of the occurrence of a stroke or a coronary thrombosis

Group B In the group in which the degenerative changes are most marked in the principal branches and muscle vessels the danger of gangrene is considerable Secondary thrombosis of the main vessels may occur at any time following trauma or be brought about by lowered blood pressure and diminished circulation rate through intercurrent illness or operation Main vessel thrombosis has been seen following hernia operations lobar pneumonia coronary thrombosis and in fact any condition in which the patient is forced to remain in bed

Group C In the last group in which the arterial changes are predominantly distal peripheral gangrene is not very common but when it occurs it is always amenable to conservative treatment the areas of necrosis being, as a rule small and confined to the tips of the toes

PRIMARY THROMBOSIS OF THE SUPERFICIAL FEMORAL ARTERY

This relatively uncommon manifestation of *obliterative* arteritis merits separation from the commoner type of arteriosclerosis—diffuse obliterative arteritis—on account of the characteristic arteriographic appearance and clinical course

Arteriography shows occlusion of a segment of the superficial femoral artery extending from a point an inch or so distal to the origin of the profunda femoris from the common femoral artery down to the level of the adductor hiatus (Fig 461) The extent of the blocked segment is remarkably constant A large branch probably the anastomotica magna is usually seen leaving the femoral artery immediately below the block It seems probable that the brisk blood flow through this artery

Fig 46 Arteriogram showing primary femoral thrombosis The oc luded segment extends from the opening in the adductor magnus to origin of the deep femoral artery

and through the profunda femoris above determines the limits of the block by pre enting the p ox mal and distal extension of the clotting process

On *a priori* ground t would appear likely that the thrombosis begins distally at the level of the adductor hiatus where the artery becomes relati ely fixed.

The popliteal and tibial vessels appear normal or show the minimum sign of arterial disease in sharp ontrast with the appearance in senile obliterati e arteritis where the popliteal artery in particular shows gross narrowing and irregularity

Calcification in the arterial wall is not seen in this class The collateral anastomoses are well developed

Clinical Features

The clinical features are quite characteristic enabling the surgeon to distinguish between a primary thrombosis and that secondary to senile obliterative arteritis In both conditions the patient complains of intermittent claudication in the calf muscles. In primary femoral thrombosis the surprising feature is the healthy appearance of the limb The nutritional changes in the skin and nails subcutaneous tissues and muscle wasting found in a greater or lesser degree in senile obliterative arteritis complicated by secondary thrombosis are most noticeably absent A strikingly healthy looking limb in a patient past middle age complaining of effort pain in the calf muscles on exercise is almost pathognomonic The presence of a good pulse in the groin together with absence of oscillations above and below the knee confirms the diagnosis

The blood pressure is usually normal in contrast with the hypertension so commonly found in senile obliterative arteritis

Prognosis

The importance of distinguishing primary thrombosis of the femoral artery from thrombosis secondary to senile obliterative arteritis lies in the different outlook for life and limb In primary femoral thrombosis peripheral gangrene often massive involving the foot or even whole leg below the knee due to extension of thrombosis or more limited necrosis due to purely distal thrombosis is the rule

In senile obliterative arteritis, coronary thrombosis or a stroke commonly forestalls severe ischaemic changes requiring high amputation The prognosis in primary femoral thrombosis is comparatively good for life but bad for the limb In senile obliterative arteritis at any rate where the main vessels are principally involved the reverse is the rule

THE MANAGEMENT OF PERIPHERAL GANGRENE

The method of approach and details of treatment will be described under the following headings

1 The Plan of Action
2 The General Care of the Patient
3 Conservative Treatment
4 Special Problems in Diabetic Gangrene
5 The Technique of High Amputation

THE PLAN OF ACTION

The Surgeon s First Duty

Gangrene is an acute condition and should be given the immediate attention accorded to other acute conditions An immediate decision can and must be reached on the crucial question of major amputation or saving the limb Experience has shown that the decisive factor is patency of the popliteal or superficial femoral arteries The popliteal pulse is often extremely difficult to feel especially in old people with thickened arteries and fibro-fatty pads in the popliteal fossa

The problem is solved by the use of the oscillometer (Fig 462) The cuff is placed immediately below the knee If the oscillometer records good pulsation, with certain exceptions mentioned later in this paper an attempt should always be made to save the limb Absence of pulsation immediately below the knee is conclusive proof of thrombosis of the popliteal or femoral arteries In my own experience, the conservative treatment of gangrene however limited and however healthy the limb may appear is *hopeless if the main vessels are thrombosed* and amputation through the thigh should be advised. Hence a decision on the main issue can be reached in a few minutes Oscillometry is not as widely used as it should be in this country in the investigation of vascular diseases If an oscillometer is not available, a simple and accurate clinical test is pallor of the foot on elevation *Immediate pallor* as opposed to gradual paling is diagnostic of a main vessel block

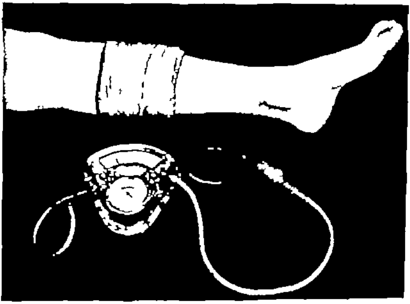


Fig 462 Boulitte modification of the Pachon oscillometer

Gangrene in the Presence of Thrombosed Popliteal or Femoral Arteries Amputation through the thigh should be advised How soon the operation is carried out depends on many factors and will not be discussed in this paper Obviously a patient of advanced age and short expectation of life with limited and painless gangrene, need not be subjected to major amputation

Gangrene in the Presence of Patent Popliteal and Femoral Arteries Generally speaking, it is worth while attempting conservative treatment with a view to saving the limb It will not always be successful There are however certain contra indications to local treatment in spite of patent main vessels. Some are absolute and some relative

Contra indications to Conservative Treatment in the Presence of Patent Main Vessels

1 *Gangrene of the 1st Toe* (Fig 463) Local amputation of the 1st toe is seldom a satisfactory procedure The wound either fails to heal or if healing takes place, rapidly breaks down While in no sense an absolute contra-indication, it is probably

unwise to advise local amputation of the first toe unless the vascular condition of the foot is unusually good and the area of gangrene limited

Fig 463 Gangrene first toe

Fig 464 Senile gangrene of toe with ulceration on the dorsum of the foot.

2 *Gangrene Extending on to or Associated with an Arteriosclerotic Ulcer on the Dorsum of the Foot* (Fig 464) If gangrene has extended on to the dorsum of the foot or there

is an arteriosclerotic ulcer exposing the extensor tendons the outlook is very poor Major amputation is probably the wisest policy

3 *Severe Rest Pain Due to Ischaemic Neuritis* Severe pain accompanying gangrene of the foot may be due to any of three causes

(a) SEPSIS Infection imprisoned under a dry hard scab gives rise to intense pain usually confined to the affected toe but may have a wider distribution if infection has spread into the sole of the foot

(b) ERYTHRALGIA Lewis (1946) used the term erythralgia to denote the intense burning pain from the arteriolar engorgement produced by metabolites not

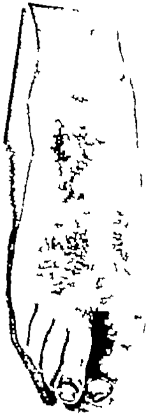


Fig 465 Indolent cellulitis of foot in a patient with senile gangrene and good oscillations above the ankle

being removed at a sufficient rate by the reduced circulation The pain involves several toes or even the distal half of the foot. The skin over the affected area is red and hyperaesthetic Overfilling of the arterioles can be prevented and the pain relieved by elevation vasodilatation of the small arteries or by constriction of the arterioles by cold Erythralgia may occur quite early in obliterative arteritis which is often accompanied by vasospasm of the small arteries of the foot and is not in itself a contra indication to conservative treatment Erythralgia must be distinguished from the very similar burning pain due to ischaemic neuritis

(c) ISCHAEMIC NEURITIS The pain of ischaemic neuritis is partly deep and partly superficial in character Involvement of the nerves to muscle and periosteum gives

rise to a constant aching or throbbing pain diffuse in its distribution and involving the distal half or even the whole foot The superficial element like much superficial pain is burning in character and tends to be paroxysmal and often agonising Pain of this type is improved by dependency and increased by elevation Ischaemic neuritis is indicative of widespread obliteration of the smaller vessels In spite of good pulsation in the main vessels pain of this type is an absolute contra indication to local treatment

4 *Oedema of the Limb and Foot* Oedema of the limb and foot due to deep phlebitis is not a common accompaniment of obliterative arteritis When present however local amputation is doomed to failure Oedema due to deep phlebitis must be distinguished from the inflammatory oedema associated with secondary infection of the gangrenous toe or neighbouring tissues

5 *Indolent Cellulitis of the Foot* (Fig 465) A peculiar indolent cellulitis involving the dorsum of the foot is occasionally seen in senile gangrene Response to sulpha drugs or penicillin is disappointing The cellulitis appears to be due to low grade infection but is probably principally a manifestation of ischaemia and possibly local venous thrombosis The presence of this type of cellulitis is an absolute contra indication to conservative management

THE GENERAL CARE OF THE PATIENT

Nutrition

Intensive study of nutritional problems in health and disease during recent years has resulted in a better understanding of the alteration in the composition of blood and tissue fluids associated with trauma and other pathological conditions The importance of the correction of these changes in the reduction of mortality rates, incidence of complications and promotion of rapid healing has been one of the major advances in surgery of the last decade

The problem of improving nutrition is of great importance in patients with peripheral gangrene many of whom through toxaemia pain, lack of sleep and anorexia have reached a state of severe malnutrition which must be corrected before separation of the dead tissue and repair can take place The risks attached to high amputation are also greatly increased The mode of correction of malnutrition in elderly patients with ageing tissues is one of the most important problems in geriatrics still awaiting solution

Rehydration and replacement of electrolytes restoration of diminished blood volume and depleted plasma and tissue protein and the correction of anaemia should be undertaken as rapidly as possible The correction of anaemia by blood transfusion rehydration and the replacement of minerals is a simple matter Restoration of blood volume and plasma protein levels and replenishment of depleted stores of body protein is no easy matter Considerable ingenuity and attention to individual tastes are required to devise a suitable dietary regimen The difference between prescribing a suitable diet on the patient s drug sheet and the ingestion of it by the patient is insufficiently appreciated by surgeons many of whom do not take the precaution of visiting the ward kitchen and inspecting the returned trays It is essential to verify that the food has in fact been consumed and, if not the reasons for refusal fully investigated and the necessary alterations made to suit the individual patient

The patient should be put on a diet containing 300 gm of protein and giving 3000 to 3500 calories daily It is not easy task to devise a palatable and varied diet containing so much protein. The problem has been greatly simplified by F Fletcher (1948) and his suggestions put into practice with the kind assistance of Messrs Benger s Limited Additional nourishment which cannot be conveniently included in an appetising menu can be supplied very simply as Benger s food reinforced with casein and glucose

BENGER S FOOD	CASEIN	GLUCOSE	PROTEIN	CALORIFIC VALUE
4 pints	7 ozs.	4 ozs.	182 gm.	3 3

(part of Benger' contributes 463 calories and 2 8 grams of protein and is equivalent to calorific value to 4 ounces of casein)

As much of this mixture as is necessary to make up any deficiency in the diet is given between meals and last thing at night No difficulty has been experienced in persuading patients to take the mixture provided the patient s individual tastes are taken into consideration with regard to flavouring

In very ill patients unable to take sufficient nourishment by mouth the full diet can be given in the form of reinforced Benger s food by intragastric drip through an indwelling Ryle s tube Blocking of the drip feed which was originally found to be a source of great difficulty has been overcome on Fletcher s advice by liquefying the mixture by adding a small quantity of pancreatin

Hormone Therapy

Although the problem of giving adequate protein has been solved there is considerable difficulty in ensuring its utilisation This problem has been partially overcome by the practical application of recent studies on the part played by the adrenal androgens in metabolism Androgens are responsible through the 17 ketosteroids (N hormone) for the retention of nitrogen. Testosterone propionate 50 to 100 mg daily intramuscularly has been shown to diminish the excretion of nitrogen—25 mg of testosterone result in the retention of 4 gm. of nitrogen The routine administration of testosterone has been of great value in promoting a rapid gain in weight, which was not attained on the same diet without testosterone

Vitamin Therapy

The patient s vitamin requirements can be satisfied by giving daily

Vitamin A	6 000 I U
Vitamin B (Becosym)	6 tablets
Nicotinic acid	00 mg
Vitamin C	200 mg

Alpha Tocopherol Therapy

The worth of vitamin E preparations (alpha-tocopherol) in peripheral vascular disorders still awaits evaluation The use of vitamin E in heart disease and muscular dystrophies has been disappointing Evan Shute (1942) claims that beneficial results in vitamin E therapy in both cardiac conditions and peripheral vascular disorders are due to decreasing capillary permeability increasing dilatation of capillaries and decreasing anorexia of cardiac and skeletal muscle

I personally feel quite convinced on clinical grounds of the value of vitamin E in the treatment of occlusive vascular conditions of the lower extremities The improvement in the nutrition of the tissues in advanced cases of obliterative arteritis with incipient gangrene is most remarkable In addition to the local improvement a marked improvement in the patient s general health and sense of well being has been noticed At least 400 to 600 mg a day should be given It is possible that an even higher dosage should be employed in patients with impending or developed peripheral gangrene Vitamin E must certainly rank as the most important element in the supportive treatment

Mental State

There are few maladies in which maintenance of morale and the will to live play a more important part in restoration of health and function than in peripheral gangrene due to obliterative arteritis

Obliterative arteritis attacking comparatively young patients as well as elderly ones causes grave social and economic problems The patient knows that he is faced with prolonged inactivity ending, at the worst in permanent crippledom from the loss of one or both legs and at the best in a return to a life of restricted activity The younger patients particularly are often faced with grave economic problems and the elderly with a sense of helplessness and dependence on others resulting in both cases in intense and often overwhelming depression

The surgeon s first and most important duty lies in combating this mental state a duty which is best undertaken personally rather than relegated to a professional psychiatrist

The human mind is remarkably resilient overcoming the consequence of the most tragic disasters if only the smallest ray of hope for the future is perceived

It is most important therefore from the point of view of the mental as well as the physical condition to reach an early decision on the treatment to be adopted and not to lea e the sufferer in lingering doubt by totally unnecessary vacillation With few exceptions where the decision to advise high amputation has been correctly made the news is welcomed with relief the patient requesting that the operation be undertaken as soon as possible Reluctance on the patient s part to accept the surgeon s decision is usually due to the economic problems of his future life Much help is obtained from the Almoner s Department which is of inestimable value in these cases

If conservative treatment is indicated the implications and prospects of success should be fully explained leaving the decision to the patient to accept or decline what may be a prolonged and unsuccessful fight to save the limb It is impossible to overstress the importance of the psychological preparation from both the humanitarian aspect and that of the successful result of surgical intervention

Euphoriants

The use of a euphoriant is of great help in dispelling the atmosphere of implicated gloom surrounding the patient Because of the lack of physical side-effects dextroamphetamine is probably the most suitable The sense of well being promoted by this type of drug also benefits the patient in making him less reliant on analgesics

The aim of conservative treatment is to promote rapid separation of the dead tissue If the necrosis is confined to the soft tissues speedy separation will take place leaving a clean granulating surface which may be allowed to heal spontaneously or the process may be hastened by the application of skin grafts These aims are secured by increasing the blood flow by decreasing metabolism and therefore lessening the oxygen requirements of the tissues and by the elimination or control of sepsis

Fundamental Errors

Three fundamental and dangerous errors are commonly made in the management of gangrene The deadly triad are

(1) *Elevation of the Limb* Elevation depletes the existing precarious blood supply sealing the fate of the limb

(2) *Application of Heat* Heating the limb increases tissue metabolism the lin requiring an increased blood flow in order to supply the greater demand for oxyger The demand exceeds the maximum that can be delivered by the arterioscleroti vessels

(3) *Keeping the Gangrenous Part Dry* Dryness and hardness of the tissues results in the sealing up of infection the only avenue of escape for which is into the tissue planes of the foot The hardened scab if entirely surrounding the digits, decreases the blood flow by strangling the deeper tissues of the toe by its contraction

The Correct Posture of the Limb

The leg should be kept slightly below the level of the head by raising the head end of the bed on 5 inch blocks The habit of elevation of an ischaemic limb thus further depriving the foot of much needed blood is still prevalent Elevation finally seals the fate of a limb whose vascular supply is inadequate The disastrous effect of raising a limb the arteries of which are reduced in calibre but the veins are normal, can be easily shown by observing the pallor which results from raising the leg Pallor of the foot on raising the leg above the level of the heart is one of the most reliable signs of an inadequate blood supply

The habit of elevation of ischaemic limbs is due to the fear of moist gangrene There is no risk whatever of moist spreading gangrene in obliterative arteritis unless there is oedema of the leg and foot due to concomitant venous obstruction from deep phlebitis or cellulitis of the foot due to severe infection Both conditions are in my opinion absolute contra indications to conservative treatment and therefore the question of elevation on this account does not arise Slight dependency of the limb has the additional advantage of retarding venous return, a principle of value in the ischaemic limb recognised by some authorities who advocate ligation of the accompanying vein in arterial injuries involving the ligation of a main artery

All the advantages and none of the objections of ligation of the femoral vein have been obtained by keeping the limb below the level of the heart The improved blood supply resulting from dependency often relieves pain a fact which sufferers often find out for themselves sleeping with the affected foot resting on a chair beside the bed Ischaemic neuritis requiring large amounts of drugs to the detriment of the patient s general condition is often completely relieved by the simple expedient of keeping the limb dependent instead of by the time-honoured method of elevation

The Correct Temperature for the Limb

The ritual application of heat to an ischaemic limb still claims its sacrifices If the dying limb succeeds in maintaining a blood supply in spite of elevation, the increased blood flow necessary to cope with the raised metabolic requirements produced by heating of the tissues will certainly be far beyond the capacity of the hard pressed collateral circulation There is no more deadly combination than elevation and heat

The application of even moderate degrees of warmth (in excess of 90 F [32°C]) may increase local tissue metabolism more than it increases the circulation A nice balance must be struck between warmth sufficient to produce some vasodilatation of the skin vessels and yet insufficient to increase the metabolism and thus demand a blood supply which cannot be met The optimum temperature at which to keep the ischaemic limb has not yet been determined The actual temperature at which cell damage occurs in tissues with a normal blood supply is 40 F (Lewis 1946) If the blood supply is impaired, tissue damage will occur at a higher temperature Until the optimum temperature has been finally decided no harm can accrue from exposing the limb to room temperature (60 -65 F) Further cooling is unwise unless it is carried out simply with the object of producing bacteriostasis until such a time as the patient is fit to stand a major amputation. The affected limb should therefore be left exposed at room temperature the rest of the patient being kept warm to encourage reflex vasodilatation

Keeping the Gangrenous Part Moist

The third member of the deadly triad in the management of gangrene is the dry hard eschar often produced by the expenditure of much care and thought on the part of the physician and much misdirected energy by the nursing staff The hard black crust imprisons sepsis which unable to escape to the surface tracks deeply along tissue planes of the toe sometimes even extending widely in the sole of the foot

The sealing up of sepsis with spread proximally into the foot is more important in diabetic gangrene where it is in fact the principal problem, than in senile gangrene Nevertheless even in senile gangrene infection plays a part and is the most common cause of pain confined to the affected toe and should be distinguished from ischaemic pain which is more diffuse usually being felt in the distal half or even the whole foot. Apart from damming back sepsis the hard eschar sometimes only involves the skin or even the superficial layers of epidermis The hardened black skin contracts gradually strangling the deeper tissues of the foot In much the same way a circumferential tanning of a burnt digit causes ischaemic changes in the deeper tissues with disastrous results Occasionally if the hard black toe is softened by saline soaks and petrolatum gauze the blackened tissue can be peeled off like a rubber cot from a finger or the tan from a superficial burn, revealing a healthy toe even partially epithelialised underneath

Improvement of Blood Supply

1 Sympathectomy

The quickest most radical and generally most satisfactory way to improve the blood supply is by sympathectomy In diffuse obliterative arteritis particularly there is often a marked degree of spasm of the smaller arteries Radiological evidence

of calcification of the main vessels is no contra indication to sympathetic denervation. Some of the most successful results of sympathectomy in senile obliterative arteritis have been in patients with visible calcification of the main vessels. Even if there is no evidence of abnormal vasoconstriction, release of normal tone will increase the blood flow. Generally speaking, lumbar ganglionectomy should be carried out in patients below the age of 60 provided their general condition does not contra indicate operation. The 1st, 2nd and 3rd lumbar ganglia with the intervening chain should be removed in order to be certain of adequate denervation. Jepson and Ratcliffe, working in my Department, have shown that the usual operation removing the 2nd and 3rd ganglia is apt to result in incomplete denervation, whereas addition of the 1st ganglion makes adequate denervation certain. In patients over 60, lumbar ganglionectomy is probably unwise. If however the general cardiovascular condition is satisfactory and there is evidence of marked arterial spasm, it would be reasonable to undertake sympathectomy in older patients. In patients upon whom operation is considered to be an unjustifiable risk, chemical destruction of the sympathetic chain with 10 per cent phenol (Haxton) is worth considering.

2. Paravertebral Block with 10 Per Cent Phenol

Chemical destruction of the lumbar ganglia has proved to be of great value in patients in whom lumbar ganglionectomy is contra indicated on general grounds or because of their age. The use of alcohol for this purpose has been almost entirely abandoned on account of the not infrequent occurrence of muscular palsies and severe neuralgia due to the unavoidable inclusion of spinal nerves in the field of injection. Mandl and Rabinovici (1947) showed in cats that 6 per cent phenol had a selective action on the sympathetic ganglia causing complete destruction without damaging the spinal nerves. H. A. Haxton (1947), working in the Neurovascular Unit at the Manchester Royal Infirmary, suggested using 6 per cent phenol for paravertebral block of the lumbar chain. Haxton's early cases using 5 c.c. of 6 per cent phenol showed evidence of partial sympathetic denervation unaccompanied by any undesirable sequelae. In order to accomplish more complete destruction of the lumbar ganglia, Haxton increased the strength of the phenol solution to 10 per cent and the quantity injected to 10 to 15 c.c. Paravertebral block with 10 to 15 c.c. of 10 per cent aqueous solution of phenol has been used in the Neurovascular Unit at Manchester in a large number of patients since May, 1947, with gratifying results. So far no complications of any sort have been encountered.

Technique

(a) EQUIPMENT

Labat syringe
Fine needle for intradermal injection
7 cm and 8 cm rustless steel needles 8 to mm. in diameter
[illegible] novocain
aqueous solution of phenol

(b) POSITION OF PATIENT. The injection can be easily carried out in bed. The patient lies on his side with a pillow under the loin in order to separate the transverse processes of the lumbar vertebrae as widely as possible. It is important to keep the back as straight as practicable, avoiding either flexion or extension, and the

body in the strict lateral position with the plane of the back at right angles to the bed. The patient tends to flex the spine and slip forwards into a semi prone position unless care is taken to maintain the strict lateral position. The foot of the bed is raised on 10-inch blocks in order to encourage the phenol to seep upwards along the tissue planes around the sympathetic chain thus reaching the first lumbar or even the 12th dorsal ganglia.

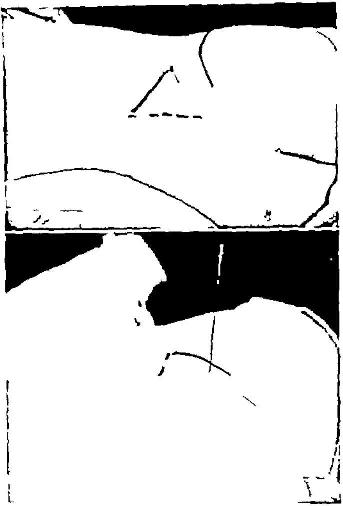


Fig. 466. Technique of injection.

Upper. Illustrating point of the injection 4 fingerbreadths lateral to the spine of the 2nd lumbar vertebra.
Lower. Insertion of the needle (see text).

The bedclothes should be removed exposing the lower extremities to room temperature (about 20°C. is ideal) and the skin temperature of the feet, preferably the inner side of the heel, is recorded at corresponding points. Readings are taken every few minutes until the skin temperature reaches a steady level.

(c) TECHNIQUE OF INJECTION. After skin preparation and isolation of the lumbar region with sterile towels, an intradermal wheal of 1 per cent novocain is raised at

a point near the outer border of the erector spinae four fingerbreadths lateral to the spine of the 2nd lumbar vertebra (Fig 466) A 16 cm needle is most commonly used but a 12 cm needle is adequate in small thin individuals. The needle is passed obliquely through the selected point and directed medially at an angle of about 30 degrees from the horizontal plane The operator should conjure up a mental picture of the relations of the erector spinae psoas muscle and vertebral bodies drawing an imaginary line from the point of injection to the front of the body of the second lumbar vertebra

By this technique the needle often passes lateral to the tip of the transverse process If possible the transverse process is felt the needle is withdrawn a little and inclined slightly upwards or downwards in order to pass above or below the bone The needle is advanced a further 4 or 5 cm through the psoas muscle until the antero-lateral aspect of the vertebral body is reached Occasionally the needle passes in front of the vertebral body piercing the aorta or vena cava. Puncture of the great vessels is quite harmless and is in fact a rather valuable indication of the position of the needle point The needle should be immediately withdrawn and reinserted at a greater angle until bone is felt When the needle is judged to be satisfactorily placed in close proximity to the lumbar chain, 2 c c of buffered 2 per cent novocain solution is injected, after careful aspiration in order to be quite certain that the spinal theca pleura, or blood vessel has not been entered

If the needle has been correctly placed a rise of skin temperature usually first detectable in the skin over the medial side of the heel below the medial malleolus will be recorded within two or three minutes A large rise in the skin temperature cannot be expected in patients with advanced arteriosclerosis In any patient however in which phenol block is indicated there will be some elevation of skin temperature A rise of even 1 occurring within two or three minutes shows that the needle is correctly placed

If no alteration in skin temperature occurs within five minutes the needle should be withdrawn reinserted at a different angle and the novocain injection repeated It is unwise to inject the phenol solution unless the point of the needle is proved to be correctly placed When the operator is satisfied with the position of the needle the phenol is injected

The phenol may not be in complete solution at room temperature If the fluid is cloudy the bottle should be warmed by standing it in hot water for a few minutes until the phenol is completely dissolved The syringe should also be warm

Ten to 15 cc of 10 per cent aqueous solution of phenol is then slowly injected and the needle withdrawn

(d) AFTER TREATMENT The patient should remain in the lateral position for twenty minutes to keep the pool of phenol in contact with the lumbar ganglia. He may then be turned on to his back and the blocks removed from the foot of the bed He should remain flat on his back for an hour after which he can return home if an outpatient with instructions to lie down for the rest of the day

Results Paravertebral block with 10 c c of 10 per cent phenol has been in constant use in the Neuro vascular Clinic in Manchester since May 1947 No after-pain or damage to spinal nerve has been observed. Examination of the limb with the electrodermatometer in successful cases shows adequate sympathetic denervation

of the foot and leg below the knee (lumbar ganglia 2 and 3) diminishing but still detectable after six months

So far complete denervation of the whole lower extremity as seen after removal of the first three lumbar ganglia has not been achieved This simple and uncomplicated procedure has been of great value in patients unfit for a more radical sympathectomy

3 Peripheral Sympathectomy (Smithwick, 1941)

Theoretically it should be possible to relieve the pain of gangrene by interrupting the sensory pathway between the forefoot and the central nervous system and at the same time improve the blood supply of the foot This may be accomplished without loss of motor power by interrupting the posterior tibial anterior tibial superficial peroneal and internal saphenous nerves (Fig 467) most of the vasoconstrictor fibres run in the post tibial nerve

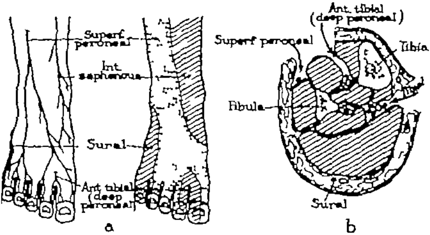


Fig 467 Nerves supplying foot. *b* Approaches for exploring nerves.

This denervation can be accomplished through two incisions beginning a hand breadth above the medial and lateral malleoli and extending upwards for about 2 inches A medial incision is made one fingerbreadth behind the medial border of the tibia the internal saphenous nerve is secured in the subcutaneous tissue the tibial origin of the soleus is then divided in the line of the incision The posterior tibial nerve is easily identified lying on tibialis posticus Great care must be taken not to injure the posterior tibial artery and its venae comites The nerve and vessels are often bound together and it is sometimes extraordinarily difficult to separate them without injury to the latter The nerve is isolated just below its last important muscular branch the branch to flexor longus hallucis

The outer incision is made one fingerbreadth lateral to the anterior border of the tibia Great care must be taken not to mistake the tendon of tibialis anticus for the anterior border of the tibia otherwise the wrong intramuscular septum will be explored The deep fascia between the tendons of tibialis anticus and extensor longus digitorum is incised and the anterior tibial nerve sought between these muscles The superficial peroneal nerve is found by reflecting the outer flap of the

incision the nerve will be found after penetrating the deep fascia or alternatively a ridge will be seen in the deep fascia which can be incised and the nerve found beneath it on the surface of the peroneal muscles

The conduction of sensory impulses from the foot may be blocked by injection of the alcohol crushing the nerve over a centimetre with Spencer Wells forceps or by division Both crushing and injection of alcohol especially the latter is apt to be followed by severe after-pain The anaesthesia following both crushing and injection of alcohol is in my experience extremely disappointing The most satisfactory result is obtained by excision of a centimetre or so of the nerve After absolute haemostasis has been secured the skin is closed with interrupted sutures

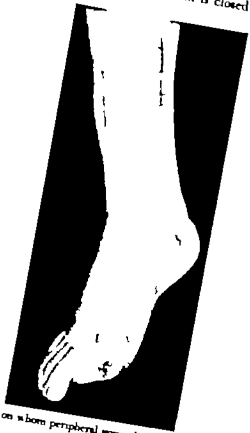


Fig 448 Patient on whom peripheral sympathectomy was performed

of the finest nylon It is rather important not to suture the deep fascia because the oedema that is bound to follow may lead to compression of the blood vessels

Results of the Operation (a) The pain in the foot is relieved but there may be a fair amount of pain in the incisions

(b) The foot is warm and dry because most of the vasoconstrictor nerves to the blood vessels of the foot run in the posterior tibial nerves therefore the foot has been sympathectomised

(c) The sensory changes in the foot after operation are extremely variable Theoretically the foot should be completely anaesthetic In one case where the nerves were thoroughly crushed with a Spencer Wells forceps the only anaes

thesia which could be found was a small patch on the dorsum of the foot between the first and second toes. In another case the foot was hypo-aesthetic but in no part was complete anaesthesia achieved. The most satisfactory results are obtained by excision of a centimetre of the nerve rather than by crushing it or injection of alcohol.

Indications for Peripheral Sympathectomy. There are, in my opinion, very few indications for this procedure. The operation is sometimes of value in patients with severe rest pain in the toes or foot but in whom major amputation is contra-indicated by age or infirmity, and secondly, in order to render the foot painless and also improve the cutaneous blood supply in patients upon whom local removal of the toe is contemplated but the line of demarcation is slow in forming and the pain severe.

Objections to the Operation. The objections to the operation which limit its more general application are:

1. The incisions in the leg do not always heal well or, if they heal, show a tendency to break down leaving painful ulcerated areas.

2. There is sometimes severe post-operative pain at the site of the operation which troubles patients as much, if not more, than the pain in the foot for which the operation was undertaken.

3. The relief of pain is problematical. It has a tendency to return after a few days although, perhaps, in a milder degree. The return of pain is more likely to occur if the nerves are crushed or injected with alcohol than if cleanly divided.

4. If adequate anaesthesia is obtained there is a considerable risk of trophic ulceration on the sole of the foot.

Local Treatment

The formation of a line of demarcation and separation of the necrotic tissue is encouraged by twice daily soaks in normal saline at body temperature. In between the soaks the affected area is dressed with gauze liberally smeared with petrolatum. Infection is controlled by the use of antibiotics or the sulpha drugs depending on the degree and nature of the infection. If gangrene is limited to the soft tissues of the terminal phalanges, separation will occur in seven to ten days leaving a clean granulating surface which rapidly heals. If, however, a large part of the whole of the toe is gangrenous, a line of demarcation down to bone occurs rapidly but complete separation is unlikely. Much time will be saved if a local amputation is then carried out.

1. Amputation through Metatarso-Phalangeal Joint

Amputation through the metatarso-phalangeal joint by a racquet incision with closure of the wound without drainage was practised by the writer for a number of years with a fair measure of success. The stem of the racquet incision should be made on the plantar aspect of the foot because (a) there is a better blood supply to the skin and subcutaneous tissues, and (b) if the wound breaks down there is dependent drainage.

Great care must be taken to keep close to the bone while dissecting up the flaps in order to avoid injury to the blood supply of the adjacent toes. Bleeding, which is

usually very slight should be controlled by hot packs and forcl pressure Absolute haemostasis must be secured but it is better to avoid leaving ligatures in the wound

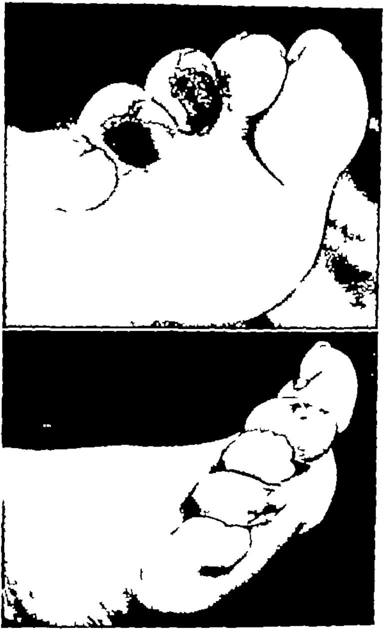


Fig 469

Upper Senile gangrene—good oscillations below knee Local amputation of gangrenous phalanges ten days after lumbar ganglionectom

Lower Toes soundly healed in twenty-one days.

if possible The wound is dusted with sulphadiazine powder and closed without drainage with as few int rrupted titches of serum-proofed silk or woven nylon as

possible The wound is then painted with Whitehead s varnish and dressed with dry gauze and plenty of wool and bandaged firmly but not tightly with a crepe bandage The wound should be left untouched for ten days The success of the procedure depends upon absolute haemostasis and closure without drainage

2. Amputation Through the Line of Demarcation

By this procedure (Fig 469) no normal tissue is traumatised There is no risk to the blood supply of the adjacent toes and no tissue spaces are opened up thus reducing the danger of infection extending into the whole of the foot The toe is simply cut off through the line of demarcation with sharp bone-cutting forceps The base of the phalanx is completely removed with fine nibbling forceps leaving the cartilage-covered head of the proximal phalanx (or metatarsal) at the base of the wound

Fig 470 Local amputation of the outer four toes in patient with senile gangrene and good pulsations in popliteal artery Note cartilage covered head of 3rd metatarsal uncovered by granulating tissue and causing delay in healing

Formerly the cartilage covering the head of the phalanx was left intact in order to minimise the risk of infection of the cancellous bone Articular cartilage however depending for its nutrition largely on the synovial fluid tends to necrose delaying healing (Fig 470) Better results are obtained by nibbling away all the hyaline cartilage thus leaving exposed cancellous bone at the base of the stump The cuff of soft tissues is allowed to fall into the socket No sutures are used The wound is dusted with sulphadiazine powder and dressed with tulle gras The healing is prompt, leaving a non-tender stump

There is a considerable risk of damaging the blood supply of the adjacent toes in amputation through the metatarso-phalangeal joint. If the wound fails to heal amputation through the thigh will have to be carried out. For these reasons I have practised for some years now the somewhat unacademic procedure of nibbling away the dead tissue piecemeal

The term diabetic gangrene has been used to describe the condition resulting from thrombosis of the terminal vessels in a diabetic subject The thrombosis may be secondary to senile obliterative arteritis or may be the result of sepsis the vascular supply of the limb as a whole being normal Thus two distinct types of diabetic gangrene must be clearly recognised namely senile gangrene in a diabetic patient and true diabetic infective gangrene

Whether or not diabetes mellitus predisposes the patient to early degenerative arterial changes will not be discussed Well marked calcification of the femoral and popliteal arteries has been observed in a diabetic girl aged 21 on the other hand gross atheroma has been found in autopsies on children who were not diabetic The controversial point does not affect the issue that gangrene associated with senile obliterative arteritis does occur in diabetic patients

It would appear that senile gangrene is more often associated with secondary infection in diabetics than in non-diabetics This fact does not alter the point that the basis of the gangrene is obliterative arteritis and the patient should be treated as such extra care being taken to control the diabetes and the sepsis

True diabetic gangrene is entirely due to the effects of neglected sepsis Owing to the hypo-aesthetic condition of the foot the severe pain usually associated with infections of the digits is reduced or absent This allows sepsis to progress until there is thrombosis of the digital vessels with resulting gangrene

Patients of this type have excellent circulation in the limb as a whole All pulses are present and the oscillometer confirms the absence of any arteriosclerotic changes These patients are commonly extremely deaf

Senile (Arteriosclerotic) Gangrene in a Diabetic Patient

Most cases of diabetic gangrene fall into this group In general the management should follow the lines laid down in the previous section on senile gangrene There are however two additional factors requiring special attention

(a) Investigation and treatment of the diabetes which must be adequately controlled

(b) Elimination of infection. Sepsis as a rule is more marked than in simple senile gangrene uncomplicated by diabetes

Management of the Gangrene If oscillations are found to be absent below the knee revealing thrombosis of the popliteal or superficial femoral arteries, amputation through the thigh should be advised

If oscillations are present below the knee showing patency of the popliteal and superficial femoral arteries an attempt should be made to save the limb except under the circumstances mentioned previously in the section on senile obliterative arteritis

It must be remembered that the outlook for both life and limb in senile obliterative arteritis with or without peripheral gangrene is distinctly worse in a diabetic patient Where a certain risk might be taken to save the limb in simple senile gangrene with a reasonable prospect of success no such latitude is permissible in the presence of diabetes

Control of the Sepsis Infection, never a serious problem in simple senile gangrene is not uncommonly a prominent feature in diabetic patients often determining the fate of the limb

Stabilisation of the diabetes is often impossible in the presence of active infection It may not be possible to clear up the sepsis without incision and drainage or removal of a toe nail The resulting wound often fails to heal owing to the deficient blood supply The surgeon is thus forced into undertaking a major amputation

Every effort must be made to clear up any sepsis as soon as possible with the aid of the sulpha drugs and antibiotics in addition to the local measures described in the previous section

True Diabetic (Infective) Gangrene

True diabetic (infective) gangrene is much less common than senile gangrene associated with diabetes The importance of recognising the existence of this group lies in the fact that the limb can nearly always be saved. No other type of peripheral gangrene is so amenable to local treatment as the infective gangrene complicating severe diabetes There is no evidence of generalised arterial disease The oscillometer records normal pulsations throughout the limb Gangrene is simply due to local thrombosis brought about by prolonged pent-up sepsis The anaesthetic or hypo-aesthetic condition of the foot due to diabetic neuritis delays the early recognition of local infection which tracks widely in the tissue planes of the toe and foot On account of the absence of pain in the foot the progress of the infection is not appreciated until too late to prevent its spread

Investigations Various types of local infection may be found including paronychia extending to pulp space and finally involving bone or tendon sheath primary osteomyelitis of the shaft of phalanx or metatarsal suppurative synovitis suppurative arthritis (Fig 471) Purulent discharges, if present should be carefully examined Knowledge of the sensitivity of the organisms to penicillin and streptomycin is of fundamental importance

The foot should be x rayed in order to determine the presence or absence of osteomyelitis or suppurative arthritis Apart from bone necrosis, the soft tissue shadow particularly the appearance of gas in the tissue planes may indicate the extent of the infection in the sole of the foot

Treatment in the Medical Ward The problem is primarily a medical one as the diabetes is in a very unstable state requiring the constant vigilance of the physician The patient should therefore be left in the physicians ward under the immediate care of his resident, and of a nursing staff trained in the management of diabetics. The physician should prepare the patient for operation and undertake the immediate post-operative treatment, which is principally concerned with the control of blood sugar

Effective blood levels should be ensured at the time of operation by beginning the course of antibiotic and chemotherapy twelve hours before excision of the gangrenous tissue Two hundred thousand units of penicillin are given intramuscularly every three hours or a more recent alternative 1 000 000 units of the slow release preparation once daily Streptomycin, 0 5 gm is given intramuscularly every six hours In addition 1 5 gm of sulphamethazine may be given every six hours.

The surgeon must be ruthless in the removal of the gangrenous tissue (Fig 472) The affected toe or toes are removed by a racquet incision, the stem of which should be placed on the plantar aspect of the foot Necrotic tendons or metatarsals are removed together with the gangrenous digits All pockets of pus in the tissue planes of the sole of the foot are opened up The incision in the sole of the foot should be carried down to the heel or even continued into the calf if necessary Considerable ingenuity is required to plan the incisions so as to include all the dead tissue and drain all the infected tissue planes If necessary the foot may be split vertically or a full thickness wedge resected Haemostasis is secured by hot gauze

Fig 47 X-ray of foot in true diabetic gangrene showing suppurative arthritis of metatarso phalangeal joints (Dr Gray case)

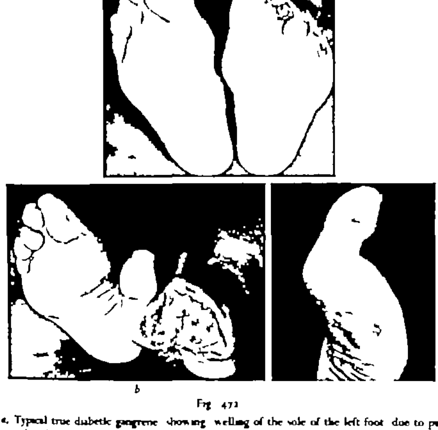
packs ligatures being avoided if possible The wound is then lined with tulle gras from the mesh of which surplus grease has been removed in order to allow free drainage of exudates The wound is then lightly packed with gauze soaked in a solution of streptomycin (200 units per c c) and covered with cellophane to delay evaporation The patient is nursed in the semi-prone position, as far as possible to secure dependent drainage

Within a few days of dealing radically with the sepsis the diabetes will be stabilised and the most dangerous period passed The necessity for constant supervision by the physician will now be ended and the patient should be transferred to the surgeon s ward.

Treatment in the Surgical Ward After the stabilisation of the diabetes the problem becomes primarily surgical being concerned with the promotion of rapid healing in the affected limb and the restoration of function

No hard and fast rules can be laid down for this stage of treatment. The tulle gras is left in situ as long as possible the length of time depending on the amount of purulent exudation Similarly the gauze packing may be re moistened with streptomycin solution or changed twice daily depending on the degree of soiling

a



b

Fig 472

a. Typical true diabetic gangrene showing swelling of the sole of the left foot due to pus in the tendon sheath and fascial spaces (By courtesy of N F Kirkman, Esq F R.C.S)

b Appearance few days after wide excision of the gangrenous toes and drainage of the fascial spaces in the sole of the foot

The end result—a useful painless foot.

The dressings are remarkably painless because of the hypo-aesthesia due to the associated peripheral neuritis

Delayed primary or secondary suture is sometimes possible The healing of large granulating areas may be hastened by early skin grafting Rapid healing is the rule leaving a surprisingly useful and painless though often misshapen foot

Great care must be taken to impress the patient with the necessity of strict adherence to diet laxity leading for certain to further gangrene

THE TECHNIQUE AND MANAGEMENT OF HIGH AMPUTATION IN SENILE GANGRENE

Healing by first intention should be the principal consideration influencing the choice of level and technique of amputation in elderly patients with senile gangrene. Very few of them are able to manage a prosthesis and therefore the instrument maker's likes and dislikes need not be taken into consideration in planning the amputation. In recent years there has been a tendency to return to the low thigh amputation of the Stokes-Gritti type with a view to obtaining an end-bearing stump and to reduce operative shock. There is much to be said in favour of end bearing stumps for elderly amputees provided sound and rapid healing can be assured. The numerous modifications in technique which have been introduced in this type of amputation in order to eliminate prolonged sero-sanguineous discharge and secure healing by first intention bears testimony to the difficulties in securing certain healing and early ambulation.

Pre-operative Preparation

After the decision to amputate has been reached, the patient's nutritional state, renal function and cardiovascular and respiratory systems should be reviewed. Rehydration, correction of any hypoproteinaemia, and restoration of haemoglobin must be complete. Thorough pre-operative preparation need never be shortened through fear of increasing toxaemia from dead tissues or sepsis in toe or foot. Pain and toxaemia can be controlled by refrigeration; pent up sepsis in the toe or foot can be drained and infection controlled by antibiotics. Thorough preparation is of fundamental importance if the operative mortality is to remain low and sound healing to be assured.

Anaesthesia

The choice of the most suitable anaesthetic can be safely left to the anaesthetist. Anybody who is fit to have the operation is fit to have modern anaesthesia. As long as the services of a good anaesthetist are available there is no need to consider the use of refrigeration anaesthesia. Refrigeration of a thick thigh is not easy and the resulting anaesthesia is by no means always complete. The technique is messy and trying for the patient, the surgeon, and the nursing staff alike. The most serious objection to refrigeration anaesthesia is the necessity for using a tourniquet. Circulatory arrest in addition to refrigeration undoubtedly retards healing. In my opinion refrigeration should only be used for preservation of a gangrenous limb in order to prevent toxaemia where time is required for pre-operative preparation or where amputation of both legs is necessary. One limb can be refrigerated until the patient is fit to undergo the second operation. Amputation is carried out through healthy uncooled tissues proximal to the tourniquet under general or spinal anaesthesia.

Level of Amputation

In order to be certain of healing by first intention it is wiser to amputate at a slightly higher level than that usually advocated. If the vessels are divided as they pass through the adductor opening it will be found that the bone is sectioned about 9 inches below the tip of the great trochanter instead of 12 inches as preferred by the limb fitter.

Technique of Amputation

The following points are of fundamental importance in amputation for arteriosclerotic gangrene (1) A tourniquet must not be used (2) Cut short flaps containing all tissues (3) Close wound without drainage

1 *The Evils of the Tourniquet* I had the opportunity of examining at autopsy the site of application of the tourniquet in two patients who had succumbed to amputation carried out elsewhere Many of the muscle vessels were found to be thrombosed However carefully the tourniquet is applied damage to the smaller arteries—especially if arteriosclerotic—leads to thrombosis and occlusion of the very vessels upon which the nutrition of the stump depends venous thrombosis caused in the same way is a common cause of oedema of the stump

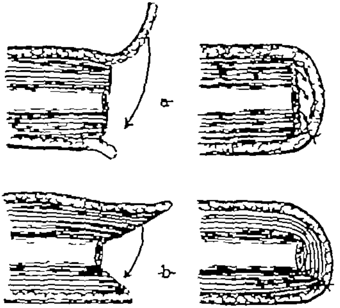


Fig 473 Technique of amputation through the thigh in senile or diabetic gangrene

Large anterior flap of skin, subcutaneous tissue and deep fascia showing dead space where blood and serum from cutaneous muscle may collect.

b Correct method of amputation

Tourniquets are undoubtedly responsible for much post-operative pain The difference in post-operative discomfort after amputations with and without a tourniquet is most striking Those patients who have experienced both often state that the post-operative pain is less after amputation through the thigh than that after appendicectomy or herniorrhaphy

The Flaps A long anterior flap consisting of skin and fascia only should never be used in amputations for arteriosclerotic gangrene because of the poor blood supply and risk of necrosis the shorter the flap the better (Fig 473) The anterior and posterior flaps should be almost equal in length the anterior being very slightly longer The greater tendency of the posterior flap to retract will prevent a terminal scar All the tissues down to bone should be divided in the same plane with as few cuts as possible The anterior incision is carried through the superficial part of the

vastus internus down to bone and continued through the quadriceps and vastus lateralis The first 2 inches or so of the posterior flap is then made on the medial side sartorius divided, and division of the deeper part of the vastus medialis completed The vessels are identified as they are about to pass through the opening in the adductor magnus The tendon of the adductor magnus which is often adherent to the vascular sheath is carefully divided The vessels are next isolated divided and ligated with silk The posterior flap is then completed with one sweep of a long amputation knife

Tight Closure of the Wound Great attention must be paid to haemostasis Obstinate oozing from the bone end can be controlled with a small patch of oxycel gauze A few bleeding points in the various intramuscular septa will require ligation Trouble some bleeding sometimes occurs from small vessels close to the linea aspera. Special care must be taken to stop bleeding from the small artery and vein which lie in the middle of the sciatic nerve If the bleeding does not respond to pressure of hot packs the vessel should be picked up with fine mosquito forceps and ligated with the finest silk care must be taken to avoid including any nerve fibres

Mass ligation of nerve and vessels must never be done The artery tends to retract as the ligature is tied and so escape inclusion. There is also the general objection to ligature of a nerve The result is a haematoma within the sciatic nerve sometimes several inches long and giving rise to great pain

After haemostasis has been secured the wound is dusted with sulphadiazine powder and the cut muscles approximated with 3 or 4 large sutures including the deep fascia Suture of the opposing raw surfaces of muscles stops all oozing and dead spaces are eliminated The skin is then closed with interrupted sutures of fine silk. Accurate approximation of the skin edges is most important If the flaps have been correctly cut they will just meet under slight tension The stump will be firm and there will be no dead spaces in which serum or blood can collect.

The suture line is painted with Whitehead's varnish and covered with a few pieces of gauze The dressing is kept in place by bandaging the stump firmly and evenly with a 6-inch gauze roll Cotton wool is then applied, special care being taken to protect the end of the stump Additional pads are applied to obliterate dead space posteriorly between the bellies of the biceps The stump is then firmly and evenly bandaged into the correct shape by using two 6-inch crepe bandages sewn together It is most important to avoid rotating the soft tissues while applying the pressure bandage The pressure must be firm enough to control capillary oozing but not enough to interfere with the circulation in the stump

Post-operative Management

The stump is immobilised between sandbags and a roller towel for twenty-four hours after which time movement is encouraged Originally the wound was left untouched until the stitches were removed on the twelfth day It was found however that the gauze on the under surface of the thigh hardened by dried blood irritated the skin sometimes producing ulceration These ulcers resembling bed sores took a long time to heal For this reason, the stump is re-dressed on the sixth day Stitches are removed on the twelfth day The day upon which the patient is allowed out of bed depends largely on the patient himself The younger and more active are encouraged to get up on the third or fourth day The frail and elderly are

better left in bed until after the stitches have been remo ed and the stump soundly healed Recently an umbrella of antibiotics has been used to cover the first three post-operative days

Mortality and Results

The mortality of amputation through the thigh should be very low in properly prepared patients In my series of 198 amputations for senile and diabetic gangrene there has been only one death—an elderly diabetic with senile gangrene who died on the second day after operation following inhalation of vomit All cases have healed by first intention and there has been no sepsis apart from occasional slight skin infection around the stitches

CONCLUSION

In concluding this brief account of the method of management of senile and diabetic gangrene the writer wishes once again to stress the importance of early recognition and treatment Failure to appreciate the urgency of the condition leads to unnecessary suffering A plea is made to regard gangrene as an acute condition which should be treated on general surgical principles—principles too often abandoned in fa our of medieval mysticism

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